Examining Empathy in Autism Spectrum Disorders:

Cognitive, Subjective and Physiological Correlates of the Perception of Pain

Michelle Hoogenhout

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Department of Psychology

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To my grandparents, who did not get the see the completion of this work.

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ABSTRACT

Social-communication impairments in autism spectrum disorder (ASD) are often ascribed to deficits in empathy. I argue that social-communicative deficits in ASD stem from impairments in specific aspects of empathy, rather than a general empathy impairment. Empathy is defined as the sharing of another's emotion (affective empathy), understanding others' mental states (cognitive empathy), and regulation of one's own emotional state (self-regulation). Empathy can also lead to muscle mimicry and empathic concern for another's wellbeing. I argue that empathy should be measured on multiple levels: cognitive, subjective and physiological. Particularly, measurement of autonomic regulation can contribute to characterising the empathy profile in ASD. Furthermore, confounding factors such as lack of understanding of one's own emotions, or alexithymia, must be accounted for when measuring empathy.

I measured subjective trait empathy ratings in people with varying levels of autism traits (N_1 = 519 & N_2 = 98, ages 14 - 45). I also investigated the association between physiological arousal, trait empathy, and empathic concern for (1) sensory pain and (2) facial pain expressions, controlling for alexithymia (N = 98); and examined the evidence for atypical autonomic arousal at rest and during empathy-induction in individuals with ASD. Autism traits were negatively correlated with cognitive empathy and self-regulation, but were not associated with atypical affective empathy *per se.* However, individuals with poor self-regulation showed heightened subjective affective states, whereas alexithymic individuals showed reduced affective empathy to facial pain expressions. Regarding the autonomic regulation of empathy, there was a significant association between autonomic arousal and affect regulation: Low sympathetic arousal and concurrent high parasympathetic arousal at

rest predicted smaller changes in personal distress during pain observation than did autonomic co-inhibition. However, resting state arousal did not predict absolute affective state levels or dispositional empathy, and was not associated with amount of autism traits.

In conclusion, the findings do not support the hypothesis of global empathy deficits in ASD. The results suggest that interventions focusing on own-emotion identification and self-regulation skills are important, but caution against the over-hasty adoption of interventions targeting resting state autonomic arousal, which was not related to either ASD or dispositional empathy.

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List of Abbreviations

ADM	Abductor Digiti Minimi
ADOS-2	Autism Diagnostic Observation Schedule, Second Edition
AI	Autism Index
AQ	Autism Spectrum Questionnaire
APA	American Psychiatric Association
ASD	Autism Spectrum Disorder
BOBYQA	Bound Optimisation by Quadratic Approximation
dZ	Change in Impedance due to Respiration and Heart Beat
EKG	Electrocardiography
ECS	Emotional Contagion Scale
EMG	Electromyography
FDI	First Dorsal Interosseous
FP	Faux Pas
HR	Heart Rate
ICG	Impendence Cardiography
IRI	Interpersonal Reactivity Index
PEP	Pre-Ejection Period

R^2_M	Marginal Coefficient (Fixed Factor Coefficient of Determination)
R^2_C	Conditional Coefficient (Total Model Coefficient of Determination)
RDoC	Research Domain Criteria
REML	Restricted Maximum Likelihood
RSA	Respiratory Sinus Arrhythmia
SCL	Skin Conductance Level
SRPP	Student Research Participation Programme
TAS-20	Toronto Alexithymia Scale – 20 Item
VU-AMS	Vrije Universiteit Ambulatory Monitoring System
VU-DAMS	Vrije Universiteit Data Analysis and Management Software

CHAPTER 1.

INTRODUCTION

Humans are a social species. We rely heavily on establishing and negotiating partnerships and on social learning to survive (Cacioppo, 2002). In turn, bonding, working towards joint goals, and learning from others all rely on the ability to understand others' mental states, to feel appropriate concern for others' well-being, and to regulate our own behaviour. In short, social functioning requires empathy.

Empathy involves a wide range of feelings and thoughts that can lead us to act in caring and compassionate ways. Empathy arises from and results in physiological changes in the central and peripheral nervous systems, such as activation of brain regions involved in feelings of emotion, and changes in heart rate and muscle activation, that allow us to represent another's affective and mental state in ourselves. In brief, empathy involves the sharing of another's emotion, understanding others' mental states and the causes thereof, and regulation of one's own emotional state. Emotion sharing leads, in turn, to feelings of concern for another's wellbeing. It is these feelings that drive social interactions.

Nowhere is the need for social functioning seen more clearly than in conditions where social functioning goes awry. Autism spectrum disorder (ASD) is one such condition. Individuals with autism have difficulties with social-communication, so that they are less likely to initiate and maintain reciprocal conversations, respond appropriately to social interactions, and use socially-directed communication such as gestures, eye contact, and facial expressions. The result is that individuals with ASD are often socially isolated, even when they wish to establish relationships. The original description of autism was of an "inability to relate… in the ordinary way to people and situations" (Kanner, 1943, p. 242).

Building on this description, some have argued that a global deficit in empathy is the driving force behind the difficulties in social functioning seen in ASD (Baron-Cohen, 2009; Baron-Cohen & Wheelright, 2004; C. Gillberg, 1992).

This thesis examines the nature of empathy deficits in ASD. To correspond with recent movements toward studying biopsychological processes in a transdiagnostic and multidimensional manner (Cuthbert, 2014; Kozak & Cuthbert, 2016), I have measured empathy at several levels of analysis; particularly, the physiological, cognitive, and self-report levels. Furthermore, autism is treated in a dimensional way, rather than focusing on between-group differences. Over the course of three studies, I examined the effect of affective, cognitive, and regulatory components of empathy on feelings of empathic concern for others and investigated the association between physiological arousal and these components of empathy. In particular, I (1) measured autonomic arousal and muscle reactivity during empathy-induction and (2) explored the correlation between these physiological indices of affective responses and participants' subjective feelings of empathic concern or personal distress. Furthermore, I (3) examined whether there is evidence that abnormal autonomic regulation at rest is associated with autism traits, and correlated (4) resting state autonomic regulation with empathic responses. It was hypothesised that abnormal resting state arousal may contribute to abnormal empathic responses in ASD, if any exist.

A novel contribution of this thesis is that activity in both branches of the autonomic nervous system are measured concurrently. This allows the interaction of the two systems to be modelled to predict empathic concern. Another novel contribution of this thesis is the application of the neurovisceral integration model and polyvagal theory, which state that resting state autonomic arousal influences social engagement and autonomic regulation, to

the study of empathy in ASD. A brief overview of the theories and their application to the study of empathy in ASD is provided in the chapter overview below.

The characterisation of the physiology of empathy holds important ramifications for the diagnosis and management of ASD and other psychological disorders. For example, it leads the way towards new intervention techniques by pinpointing which facets of empathy are impaired in ASD, and suggesting physiological processes in which it may be possible to intervene. Alternatively, physiological arousal may be used as an indicator for intervention outcome. Furthermore, the characterisation of physiological arousal at rest and during empathy-induction may lead to earlier and more accurate diagnosis by identifying potential biological markers of risk.

Overview of Chapters

Following this chapter, I will draw on the neurobiological and developmental empathy literature in Chapter 2 to argue that empathy is not a unitary concept, and that some aspects of empathy can be impaired in ASD while others are intact. The deficit in empathy in ASD is not a global one as has been argued previously. I will argue that, although the understanding of others' mental states (i.e., cognitive empathy) is impaired in ASD, the sharing of others' emotions, or affective empathy, is intact. However, regulation of affective empathy may be impaired in ASD, leading to fluctuating empathic concern, or sympathy, and prosocial behaviour.

I will present evidence from the neurovisceral integration (Thayer & Lane, 2000, 2009) and polyvagal (Porges, 1992, 2001, 2003b) theories, which propose that the autonomic nervous system – divided into sympathetic and parasympathetic branches - plays an integral role in emotional arousal and regulation. As empathic emotions share the same neural circuits and peripheral physiology of self-emotions, this implies that atypical autonomic regulation

also affects the ability to perceive and share the emotion of others. Specifically, the models propose that the parasympathetic nervous system regulates activity in brain areas involved in emotion perception and regulation, thereby promoting social engagement. Given this proposition, resting state parasympathetic arousal should be associated with state and dispositional empathy (Diamond, Fagundes, & Butterworth, 2012; Liew et al., 2011). I will argue that dual activation of the parasympathetic and sympathetic nervous systems in response to empathy-inducing stimuli is important to generate feelings of affective empathy and simultaneously down-regulate these feelings so that the observer does not become over-aroused and personally distressed. Atypical autonomic arousal may contribute to atypical self-regulation of empathy in ASD, explaining the high levels of distress and aversive reactions frequently reported in this group (A. Smith, 2009).

Chapter 3 introduces the experimental paradigm for Studies 2 and 3. Empathy was studied within an empathy-for-pain paradigm that has been well-validated in neurotypical participant groups (e.g., Avenanti, Bueti, Galati, & Aglioti, 2005; Jackson, Meltzoff, & Decety, 2005; Singer et al., 2004). Empathy for another's pain was chosen as pain stimuli elicit robust physiological and emotional responses; far greater than the observation of other emotions (Reicherts et al., 2012; Simon, Craig, Gosselin, Belin, & Rainville, 2008). Chapter 3 describes typical physiological and emotional responses in empathy-for-pain studies, and examines the results of studies that have investigated empathy for pain in ASD. I also provide a rationale for the studies contained in this thesis, and discuss the hypotheses pertaining to all three studies.

Chapter 4 introduces the general methods used within the three studies presented in this thesis. In this chapter I will explain details of participant recruitment and ethical approval. Physiological, cognitive and self-report measures that are used in more than one study are discussed. I will also describe the main method of data analysis, namely mixed-

effects modelling, and its importance for use with repeated-measures dimensional data. Methods and measures specific to the individual studies are described in Chapters 5 to 7.

Chapter 5 (Study 1) examines empathy at the self-report level, and asks the question: To what extent are each of the different components of empathy - affect, cognition, and self-regulation - associated with autism traits? Self-report evidence is presented that dispositional and performance cognitive empathy as well as dispositional self-regulation are impaired in ASD, but affective empathy is intact in non-alexithymic individuals.

Chapters 6 and 7 (Studies 2 and 3) expand on Chapter 5 by investigating empathy at the physiological level. I investigate the association between resting state physiological arousal, physiological reactivity to empathy-inducing stimuli, and self-reported empathic concern and personal distress using electrocardiographic, impedance cardiographic, electrodermal, and electromyographic methods. I investigate empathy for two types of stimuli within these chapters: empathy for sensory pain (Chapter 6) and empathy for facial expressions of pain (Chapter 7). These two sets of stimuli were chosen because the former does not require recognition of facial expressions, an ability which may be impaired in ASD. In the latter design (Chapter 7), participants can only rely on facial expressions to make judgements about the pain's intensity. This design is closer to what may be experienced in everyday life, where an observer often only sees someone's reaction to distress, not its cause, and needs to be able to interpret the facial communication of pain successfully to respond appropriately.

Chapter 8 presents a general discussion of the three studies. I discuss the results in the context of current theoretical perspectives, and examine methodological issues and limitations of the studies. I conclude by examining the implication of the findings for the theories of physiological regulation of empathy, and for intervention strategies in ASD.

CHAPTER 2.

THEORETICAL FRAMEWORK

In this chapter I first describe autism spectrum disorder (ASD). Next I discuss common definitions of empathy and consider a proposed physiological mechanism of empathy. I argue that empathy is best understood from a neurobiological framework, and use a definition of empathy that best fits within this neurobiological framework. I explore how empathy has been conceptualised within the ASD literature, and how these different definitions have shaped thoughts around empathy in ASD. I present evidence that empathy is multi-faceted and that not all aspects of empathy are impaired in ASD.

Having discussed empathy, I turn to theories on the association between autonomic arousal, social engagement and empathy. I discuss the implications of these theories for studies of autism spectrum disorder, and in particular, the capacity for feeling empathy and concern in ASD. Although theories of autonomic arousal make valuable contributions to the study of social engagement in ASD, they also have some limitations. I finish this chapter with a critique of the outlined autonomic theories, before turning in Chapter 3 to the specific aspect of empathy on which I focus in this thesis; namely, empathy for pain.

Autism Spectrum Disorder

ASD is defined as a heritable, lifelong neurodevelopmental disorder. Onset is usually before three years of age, although symptoms may only become apparent later in life. The Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition (DSM-5) defines ASD according to two core features: social-communicative deficits, and the presence of repetitive or stereotyped behaviour or restricted, unusually intense interests (American Psychiatric Association, 2013). Unlike the fourth edition of the DSM, the DSM-5 no longer distinguishes

between classic autism and other pervasive developmental disorders such as Asperger's Syndrome. Thus the terms autism and ASD are used interchangeably in this thesis.

Core Symptoms

The two core features of ASD broadly define the social and non-social aspects of autism. The term 'social-communication' encompasses a wide range of skills. Individuals with ASD struggle to learn language, and speech is either delayed, absent, or abnormal in quality. For example, speech may show pronoun reversal and have unusual pitch, tone or intonation. Furthermore, individuals with ASD are less likely to appropriately regulate eye contact, use or understand gestures, initiate and maintain peer friendships, and understand social communication such as body language and non-literal speech (American Psychiatric Association, 2013). In short, individuals with ASD have difficulties with social engagement.

Non-social behaviour is also affected in ASD, in that individuals with ASD may show unusually repetitive and ritualised patterns of verbal or non-verbal behaviour. Interests may either be focused on odd topics or objects (e.g. observing the spinning of a washing machine), restricted in range, or unusual in their intensity. Stereotyped motor movements, such as finger twisting, flapping or rocking, may also be present in ASD; as well as unusual sensitivity (either heightened or reduced) to or interest in sensory stimuli (American Psychiatric Association, 2013). Though not part of the diagnostic criteria, individuals with ASD often have strengths in visual and auditory perception and rote memory (Caron, Mottron, Rainville, & Chouinard, 2004; Heaton & Wallace, 2004; Mottron, Dawson, Soulières, Hubert, & Burack, 2006).

The Broad Autism Phenotype

Autism is referred to as a spectrum disorder as the diagnosis includes a wide range of functioning and intellectual ability, from mild to severe impairment (American Psychiatric

Association, 2013). Furthermore, the social-communicative deficits and restricted or repetitive behaviours seen in ASD are not limited to this diagnostic group: These characteristics follow a normal distribution in the population, and symptoms are aggregated within families of persons with ASD (Constantino, 2011; Constantino & Todd, 2003). ASD merely represents the most severe end of this continuous distribution (Sasson et al., 2013). The presence of mild, but qualitatively similar, forms of autism symptoms in the non-clinical population has led to the term 'broad autism phenotype' (Piven, 2001; Piven & Palmer, 1999). The broad autism phenotype describes individuals who do not meet diagnostic criteria for ASD, but who have social and communication deficits, anxiety, and restricted or ritualised behaviour, similar to individuals with ASD (Losh, Childress, Lam, & Piven, 2008). Both persons with ASD and those with the broad autism phenotype show high rates of comorbidities with other neurological and psychiatric disorders. Psychiatric comorbidities are of particular relevance to this study as social-communication and empathy deficits are found in many psychiatric conditions.

Psychiatric Comorbidities

Between 30 and 70% of individuals with ASD in the population (Doshi-Velez, Ge, & Kohane, 2014; Hofvander et al., 2009), and as many as 95% of clinically-referred individuals with ASD (Joshi et al., 2010), have one or more psychiatric comorbidities. The most frequent comorbid conditions are anxiety, mood disorders, attention-deficit and hyperactivity disorder, oppositional and conduct disorders and obsessive-compulsive disorder (Joshi et al., 2010; Simonoff et al., 2008).

Important for this thesis, roughly half of all individuals with ASD meet clinical criteria for alexithymia (Berthoz, Lalanne, Crane, & Hill, 2013). Alexithymia is a multi-faceted and dimensional personality trait characterised by impairments in accurately identifying and

describing feelings, separating feelings from other bodily sensations, and sharing emotions within close relationships. Additionally, alexithymia is characterised by having a poor fantasy life preferentially thinking about external facts rather than internal conditions (Taylor, Bagby, & Parker, 2003). Alexithymia may exacerbate many of the social-communicative impairments found in ASD, such as impairments in emotion sharing. Alexithymia is relevant to the study of empathy because it can affect an individual's ability to report on feelings of empathy, and to identify emotions in others (Cook, Brewer, Shah, & Bird, 2013; Lane et al., 1996; Lane, Sechrest, Riedel, Shapiro, & Kaszniak, 2000). Importantly, alexithymia seems to characterise a discrete subgroup of individuals with ASD, rather than alexithymia always being associated with high amounts of ASD traits (Bird & Cook, 2013). I will return to alexithymia later in this chapter when I discuss task performance on empathy measures in ASD.

Summary

ASD is neurodevelopmental disorder that presents throughout the lifespan with social-communication deficits and restricted or repetitive behaviours. The social-communication deficits in ASD seem particularly important to understanding the condition: From its earliest identification, clinicians have commented on the social nature of the disorder. The original description of autism was of an "inability to relate… in the ordinary way to people and situations" (Kanner, 1943, p. 242). However, social deficits are not limited to those diagnosed with ASD: The normal distribution of social-communication abilities within the general population has lead researchers to propose that studies should investigate identifiable constructs within the social domain in the whole population, not just the diagnostic category of ASD. One such construct which is proposed to underlie social functioning is empathy (Baron-Cohen, 2009; C. Gillberg, 1996). I therefore turn the discussion to the function and

importance of empathy, separate the different constructs commonly called empathy, and evaluate the evidence for deficits in empathy in ASD.

The Function and Importance of Empathy

Empathy involves a wide range of behaviours, feelings, and thoughts that allow individuals to recognise and respond appropriately to the emotional state of others (Carter, Harris, & Porges, 2009). Increased empathy is associated with cooperation, sharing, provision of help and support, and reduced aggression (Carlo, Allen, & Buhman, 1999; Eisenberg et al., 1989; Gini, Albiero, Benelli, & Altoè, 2007; Sze, Gyurak, Goodkind, & Levenson, 2012; Tone & Tully, 2014). Empathy is also related to increased social engagement and improved peer relationships (Bailey, Henry, & Von Hippel, 2008; Zhou, Hou, Zhou, & Chen, 2011).

What is Empathy?

Despite the obvious importance of empathy for social functioning, it is not easy to define empathy. Empathy has been conceptualised in many different ways, and there is a lot of controversy around what does and does not constitute empathy. The definition of empathy used in this thesis is similar to that of Decety (2011), who divides empathy into affective empathy, cognitive empathy and self-regulation. This definition was chosen because his components of empathy have strong support from the neurobiological and developmental literature (Carter et al., 2009; Decety, 2011; Decety & Jackson, 2004). Not all researchers follow this definition of empathy, and disagreement on the processes involved in empathy has shaped research in some areas, such as in ASD. I will return to this point later in the chapter; first, I examine each of the three constituent parts of empathy as defined here, and their relation to two closely allied phenomena– empathic concern, or sympathy, and muscle mimicry.

Affective empathy is the ability to be affected by and share another's emotional state (Decety & Svetlova, 2012). This sharing of another's emotion is thought to facilitate bonding and encourage perspective-taking and prosocial behaviour. Basic affective empathy is already present in infancy (Davidov, Zahn-Waxler, Roth-Hanania, & Knafo, 2013; Geangu, Benga, Stahl, & Striano, 2011; Geangu, Hauf, Bhardwaj, & Bentz, 2011; Roth-Hanania, Davidov, & Zahn-Waxler, 2011) and in non-human animals (Bartal, Decety, & Mason, 2011; Campbell & de Waal, 2014; Parr, 2001). Hence, cognitive empathy, which requires higher-order cognitive processes, is not necessary to feel affective empathy. However, some self-other distinction and emotion regulation seems important for affective empathy to lead to prosocial behaviour, as these behaviours do not usually emerge before age 2 in humans (Brownell, 2013; Roth-Hanania et al., 2011) and are linked to levels of self-awareness (Bagby, Taylor, & Parker, 1994; Bird et al., 2010; Grynberg, Luminet, Corneille, Grèzes, & Berthoz, 2010; Moriguchi et al., 2007). This awareness of where the emotion originated from separates affective empathy from emotional contagion, also termed emotion mimicry. The latter construct does not require any reflection on the origin of the emotion. In practise, however, this awareness can be hard to ascertain, and furthermore, rudimentary self-other differentiation is already present during infancy and even in the neonatal period (Butterworth, 1992; Dondi, Simion, & Caltran, 1999). Therefore, the key difference in outcome between affective empathy and emotional contagion may lie in ability to self-regulate.

Automatic affective empathy responses to others' emotions need to be down-regulated by higher-order self-regulation mechanisms in order to facilitate empathic concern and prosocial behaviour. Hence, self-regulation is included as a key component of empathy within this definition. Preston and de Waal argue that "the outcome of empathic processes is not always positive… [contagion] effects have profound practical importance, since the spread of emotion from one individual to another may be a source of error in social

interactions." (2002, p. 14). Perception of negative emotions in a target can lead to negative emotions such as anxiety or anger in an observer, even if the target's state was not directed at the observer. In other words, affective empathy may lead either to (other-oriented) empathic concern or (self-oriented) personal distress, or a mixture of these two states (Davidov et al., 2013). Which of these responses it leads to is influenced by the individual's capacity for emotion regulation. Emotion regulation refers to the modulation of experienced or expressed emotion in the service of goal-directed behaviour and can occur via cognitive, neural, or physiological means (Miller, Seifer, Crossin, & Lebourgeois, 2015; White et al., 2014). This thesis will focus on the physiological component of self-regulation within empathy; in particular, the ability to regulate autonomic threat responses when seeing another's pain.

If affective arousal is appropriately regulated, the observer may feel empathic concern for someone in distress, and show prosocial, helping behaviour and attachment (Batson, 2009; Decety & Svetlova, 2012; Eisenberg, Eggum, & Di Giunta, 2010). Whereas affective empathy is defined as feeling *as* another, empathic concern or sympathy is defined as feeling *for* another; stated differently, affective empathy is an emotional response, whereas empathic concern is the motivation to help another (Cuff, Brown, Taylor, & Howat, 2014; de Vignemont & Singer, 2006). It involves showing concern for others' sadness, pain or distress, and is correlated with altruistic and helping behaviour (Batson, 2009; Decety & Svetlova, 2012; Eisenberg et al., 2010). Empathic concern arises from appropriately regulated affective empathy, and can be heightened by cognitive empathy, but does not require sophisticated cognition (de Waal, 2008): Cats, dogs, primates and infants from the age of 6-8 months all express concern for others showing signs of pain, distress or sadness (Davidov et al., 2013; de Waal, 2008; Romero, Castellanos, & de Waal, 2010; Roth-Hanania et al., 2011). Furthermore, apes, children, dogs, and certain birds reconcile after fighting (Cools, Van Hout, & Nelissen, 2008; de Waal, 2008; Fraser & Bugnyar, 2011; Zahn-Waxler & Radke-

Yarrow, 1990). Thus, empathic concern does not seem to require sophisticated cognitive empathy, but does require regulation of affective empathy.

Without appropriate down-regulation of affective arousal, the observer may personally feel distressed. In contrast to empathic concern, during personal distress the observer's focus is primarily self-directed, and concerned with their own welfare. For example, contagious crying in babies in response to the cries of others is thought to be due to poor self-regulation leading to distress (Davidov et al., 2013). Personal distress leads to avoidance or comfort-seeking behaviour and is associated with lower levels of dispositional helpfulness (Fabes, Eisenberg, & Eisenbud, 1993; Liew et al., 2011). Personal distress is thought to interfere with empathic concern by depleting attentional and cognitive resources and motivation to help (Decety & Svetlova, 2012; DeWall, Baumeister, Gailliot, & Maner, 2008). Studies have found that starting from 1 year of age, children's personal distress decreases and helping behaviours towards others increase (Davidov et al., 2013; Zahn-Waxler & Radke-Yarrow, 1990). Although empathy involves some level of personal distress (Preston & de Waal, 2002), the key is that distress needs to be regulated for the observer's affective state to lead to prosocial behaviour.

Cognitive empathy involves conscious, purposeful awareness of others' mental states without necessarily resonating with that state (Mazza et al., 2014). Some theorists limit cognitive empathy to the understanding of others' emotions, while others use the term more generally to refer to the understanding of *all* mental states, including understanding beliefs, desires, and knowledge. This broader definition overlaps with the definition of theory of mind; the ability to understand that others have mental states and that these mental states lead to actions (Baron-Cohen, Leslie, & Frith, 1985; Premack & Woodruff, 1978). Here I use cognitive empathy to denote awareness of any mental state. Cognitive empathy includes the ability to imagine another's thoughts and feelings (i.e., to take the perspective of the other) or

to imagine how you might feel if you were in the position of the other person (Batson, Early, & Salvarani, 1997; Lamm, Batson, & Decety, 2007). It also includes being able to accurately guess at another's mental state given their posture, facial expressions or behaviour (Deschamps, Been, & Matthys, 2014; Schulte-Rüther et al., 2010; Schwenck et al., 2012). These abilities have at different times also been called emotion recognition, empathic understanding, or empathic accuracy (Ardizzi et al., 2013; Ponnet, Buysse, Roeyers, & De Corte, 2005). Other cognitive empathy tasks include understanding social intentions and faux pas (Baron-Cohen, 2008; Baron-Cohen, O'Riordan, Stone, Jones, & Plaisted, 1999). Evidence of very primitive cognitive empathy, such as distinguishing facial emotions (Field, Woodson, Greenberg, & Cohen, 1982), is present in the first year of life. However, cognitive empathy develops most rapidly from 2 years of age, and keeps developing throughout childhood and adolescence (Butterworth, 1992; Flavell, 1999).

The affective, cognitive, and regulatory components of empathy are separate components that arise from different neural regions and have different developmental trajectories (Decety & Jackson, 2004; Decety & Meyer, 2008), with affective empathy appearing early in infancy and self-regulation and cognitive empathy developing throughout childhood. Empathic concern arises from the interplay of these components. It requires affective empathy and self-regulation, but in its most basic form, only requires rudimentary cognitive empathy. These components can be separately affected, as is the case in psychopathy, where cognitive empathy is intact and affective empathy and empathic concern are disrupted (Blair, 2008). Additionally, empathy can be thought of as both a disposition, or trait, and a specific state of being (Cuff et al., 2014). Stated differently, individuals are thought to differ in the levels of cognitive, affective and self-regulatory empathy which they can draw upon in a given situation (trait empathy). However, the magnitude of an individual's empathic response may vary between different situations, depending on the

context (state empathy). Another related concept to empathy is muscle mimicry. Whereas empathic concern is the motivation to act on empathy, muscle mimicry is the unconscious, nonverbal communication of empathy. Mimicry is the propensity to imitate others' facial expressions, tone of voice, and body language (Hess & Fischer, 2014). For example, the muscles involved in frowning are activated when watching facial expressions of sadness or anger. Empathy and mimicry are closely related, and though they are often equated, in this thesis I follow Hess's distinction that affective empathy is the sharing of an *emotional state*, whereas mimicry is the imitation of *bodily movements*. Mimicry is unconscious and involuntary (Dimberg, Thunberg, & Elmehed, 2000), but not indiscriminate: In agreement with the argument that mimicry is a way to show others that you empathise (Hess & Fischer, 2014), mimicry is context dependent and increases in the presence of those with whom we feel greater affiliation. In neurotypical adults, higher trait affective and cognitive empathy scores are associated with increased muscle mimicry (Dimberg & Thunberg, 2012; Likowski, Mühlberger, Seibt, Pauli, & Weyers, 2011; Sonnby–Borgström, 2002). Moreover, like affective empathy, there is evidence that mimicry facilitates social bonding: It increases liking and perceived similarity, and enhances social interaction and prosocial behaviour (Duffy & Chartrand, 2015; Hess & Fischer, 2013; Lakin & Chartrand, 2003). To summarise then, the core facets of empathy – affect, cognition, regulation – involve the process of becoming aware of another's mental state and feeling as another; empathic concern is the motivation to act on this feeling, and mimicry is the communication of the feeling to others. Having defined empathy and its related constructs, I now turn to empathy in ASD. Empathy has been approached from a different perspective in ASD, with important repercussions for how the condition is described and researched.

Empathy in ASD

A disagreement in definitions. Neurobiological perspectives of empathy such as those of Decety (Decety & Jackson, 2004; Decety & Svetlova, 2012) and de Waal (2008) postulate that affective arousal sharing develops before cognitive empathy, and is not dependent on the latter. When observing another's emotion, affective empathy also occurs more quickly - nearly instantaneously and automatically - than cognitive appraisal of the other's mental state. However, other researchers, particularly those working within the autism field, have defined empathy in a way that puts the affective response to others' states last. For example, Lazarus et al. defines empathy as "sharing another's feelings by placing oneself psychologically in that person's circumstance" (cited in Cuff et al., 2014, p. 3). Frith writes that "empathy presupposes, amongst other things, a recognition of mental states" (Frith, 2003, p. 145). These definitions assume that a cognitive understanding of others' minds must be present before any affective arousal sharing can take place. These researchers' viewpoint that understanding others' mental states allows for affective arousal sharing is heavily influenced by 18th century philosophers such as Adam Smith, whose stance is given in the following paragraph:

> "As we have no immediate experience of what other men feel, we can form no idea of the manner in which they are affected, but by conceiving what we ourselves should feel in the like situation. Though our brother is upon the rack, as long as we ourselves are at our ease, our senses will never inform us of what he suffers…it is by the imagination only that we can form any conception of what are his sensations…by the imagination we place ourselves in his situation, we conceive ourselves enduring all the same torments, we enter as it were into his body, and become in some measure the same person with him, and thence form some idea of his sensations, and even feel something which, though weaker in degree, is not altogether unlike them. … it is by

changing places in fancy with the sufferer, that we come either to conceive or to be affected by what he feels" (A. Smith, 1790, pp. 4–5)

Adam Smith's (1790) works have influenced the emphasis on fantasy, imagination and perspective-taking in some definitions of empathy (e.g., Davis, 1980). Unfortunately, the idea that cognitive empathy is necessary for affective empathy is not supported by modern developmental and biological studies that show that activation of affective neural areas happens automatically, and that affective arousal sharing is present in babies and animals, where complex cognitive perspective-taking skills are not developed (e.g., Bartal et al., 2011; Roth-Hanania et al., 2011). In fact, A. Smith himself commented that "upon some occasions sympathy may seem to arise merely from the view of a certain emotion in another person. The passions, upon some occasions, may seem to be transfused from one man to another, instantaneously and antecedent to any knowledge of what excited them in the person principally concerned" (A. Smith, 1790, p. 6).

Because of the assumption that *understanding leads to feeling*, most previous research on empathy in ASD has heavily emphasized cognitive empathy tasks such as emotion recognition. Self-report measures such as the Empathy Quotient (Baron-Cohen & Wheelright, 2004) heavily favour questions on the attribution of mental states. Working from this perspective, Baron-Cohen and others (Baron-Cohen, 2009; C. Gillberg, 1992, 1996) have argued that there is a global deficit in empathy in ASD. However, I will argue that this is a one-sided view of the literature and the evidence needs to be re-examined from a developmental, multifaceted (affective, cognitive, motivation, regulation) perspective of empathy. I will review the evidence for intact or deficient cognitive empathy, affective empathy, self-regulation, and empathic concern in ASD, and discuss how these findings fit with theories of empathy in ASD.

A new look at empathy in ASD. Baron-Cohen and others (Baron-Cohen, 2009; C. Gillberg, 1992, 1996) have argued that there is a global deficit in empathy in ASD. There is long-standing evidence that cognitive empathy is impaired in ASD: Many individuals with ASD have deficits in recognising emotions from pictures or videos of faces (Harms, Martin, & Wallace, 2010). Likewise, it has been well established that most individuals with ASD struggle with cognitive perspective-taking tasks, attribution of intention, and understanding complex social situations, such as social faux pas (e.g., Abell, Happé, & Frith, 2000; Baron-Cohen et al., 1999; Dahlgren & Trillingsgaard, 1996; Dziobek et al., 2006; Kaland et al., 2002), though some individuals do perform well on the aforementioned tasks (Happé & Frith, 1996; Harms et al., 2010; Kuroda et al., 2011; Ozonoff & McEvoy, 1994; Paynter & Peterson, 2010). There is also evidence for reduced ability to deduce the thoughts and emotions of a conversational partner in a real-life, structured social situation in ASD (Demurie, De Corel, & Roeyers, 2011; Ponnet, Roeyers, Buysse, De Clercq, & Van Der Heyden, 2004; Roeyers, Buysse, Ponnet, & Pichal, 2001). In sum, there is good evidence that this aspect of empathy is impaired in ASD.

Although studies have generally demonstrated impairments in cognitive empathy in ASD (e.g., Baron-Cohen, 2000; Mathersul, McDonald, & Rushby, 2013; C. Peterson, 2014), the case for impaired affective empathy is much less firm. Contrary to the global empathy deficit hypothesis, most studies find intact self-reported or observer-reported affective empathy (e.g., de Coster, Wiersema, Deschrijver, & Brass, n.d.; Deschamps et al., 2014; Jones, Happé, Gilbert, Burnett, & Viding, 2010; Rogers, Dziobek, Hassenstab, Wolf, & Convit, 2006; Schwenck et al., 2012). Studies that do show reduced self-report trait affective empathy in ASD (Demurie et al., 2011; Lombardo, Barnes, Wheelwright, & Baron-Cohen, 2007; Mathersul et al., 2013b) or in persons with greater autism traits (aan het Rot & Hogenelst, 2014), have often not controlled for factors such as alexithymia, which is

negatively correlated with affective empathy. Thus, impaired affective empathy may only be present in a subgroup of ASD individuals with alexithymia, and may not be characteristic of ASD *per se* (Bird et al., 2010; Silani et al., 2008).

As alexithymia and communication difficulties may confound self-report of empathy in ASD, researchers have also investigated affective reactions such as autonomic arousal or brain activation to empathy-inducing stimuli (e.g., viewing facial emotions or distress). At the physiological level, children with autism show appropriate autonomic arousal to the distress cues of others (Blair, 1999), do not show differences in overall levels of arousal when viewing facial emotions (though they may show less habituation; Mathersul, McDonald, & Rushby, 2013a), and show no differences in empathic brain activity once alexithymia has been controlled for (Bird et al., 2010; Hadjikhani et al., 2014). The results from these studies suggest that affective empathy is at least intact. Results from other studies suggest that affective empathy responses may even be heightened in ASD: Several studies have found increased threat-related arousal changes in children with ASD to social interactions with a novel person (Neuhaus, Bernier, & Beauchaine, 2015; Vaughan Van Hecke et al., 2009), to social stressors (Edmiston, Jones, & Corbett, 2016), and when viewing others' pain (Gu et al., 2015). In sum, the weight of physiological evidence suggests that affective empathy is intact or even heightened in ASD. The inconsistency in results, and occasional threat-like responses seen in social behaviour, suggest that individuals with ASD may have impaired regulation of affective empathy. This proposition will be discussed further in the next section.

Most studies of muscle mimicry have found that both spontaneous and voluntary imitation of expressions are intact in high-functioning individuals with ASD (Deschamps, Coppes, Kenemans, Schutter, & Matthys, 2015; Magnée, De Gelder, Van Engeland, & Kemner, 2007; Press, Richardson, & Bird, 2010; Rozga, King, Vuduc, & Robins, 2013). Though some studies found impaired (McIntosh, Reichmann-Decker, Winkielman, &

Wilbarger, 2006) or delayed (Oberman, Winkielman, & Ramachandran, 2009) spontaneous mimicry, these results are inconsistent and have not been replicated. These studies suggest that individuals with ASD show nonconscious communication of shared affect.

At the behavioural level, the results in favour of intact versus impaired empathic concern are mixed. Children with ASD show displays of basic empathic responsiveness, such as concern or comforting behaviour, when observing others in distress (Scheeren, Koot, Mundy, Mous, & Begeer, 2013; though see C. Peterson, 2014). Furthermore, Deschamps and colleagues (2014) reported equal prosocial behaviour in a computer-based task in ASD and neurotypical groups. At other times, individuals with ASD seem to show less concern for others in distress (Hobson, Harris, García-Pérez, & Hobson, 2009; Sigman, Kasari, Kwon, & Yirmiya, 1992). Parents also report less prosocial behaviour in children with ASD (Scheeren et al., 2013). Again, these inconsistencies may be due to poor self-regulation coupled with intact or heightened affective responses in ASD, leading sometimes to empathic concern and prosocial behaviour, and other times to personal distress. In this conceptualisation, neither affective empathy nor empathic concern is impaired in ASD *per se*, but how stressful the situation is perceived to be, and how well the individual regulates this distress, influences the outcome.

The self-regulation aspect of empathy has almost completely been overlooked in ASD. Many studies have implicated poor general emotion regulation in a range of emotional and behavioural problems in ASD, including anxiety, aggression, and depression (see Weiss, Thomson, & Chan, 2014; White et al., 2014). Imaging studies suggest that brain areas involved in regulation, such as the prefrontal cortex and amygdala, are abnormally activated in ASD (Mazefsky et al., 2013). These findings from the general emotion regulation literature suggest that self-regulation of empathy may be impaired in ASD. Three previous studies have addressed issues around self-regulation of empathy in ASD: First, there is some self-report

evidence of heightened trait distress in ASD (Rogers et al., 2006). Second, two neuroimaging studies found heightened brain and autonomic activation when actively watching others' pain, which they argue stem from a reduction in self-inhibition of areas related to self-other representations (Y.-T. Fan, Chen, Chen, Decety, & Cheng, 2014; Gu et al., 2015). In short, though self-regulation of empathic responses has rarely been studied in ASD, findings of general emotion dysregulation suggest that this is an area that needs further investigation.

From a neurobiological perspective, there is little evidence of global empathy deficits in ASD. Though cognitive empathy and emotion regulation may be impaired, affective empathy appears intact or heightened. If self-regulation is impaired, it would explain why empathic concern sometimes seems to be present in ASD and at other times not. This hypothesis is similar to that of a different Adam Smith's (2009) theory, the empathy imbalance hypothesis of ASD, wherein cognitive empathy is impaired but affective empathy is heightened, but places emphasis on the critical role of self-regulation in the pathway from affective empathy to either empathic concern or personal distress. Whereas A. Smith (2009) hypothesises that cognitive empathy regulates affective responses, I view regulatory processes as much more broad than purely cognitive mechanisms, though an understanding of other minds can of course influence affective responses (e.g., perception of intent modulates empathic reactions; Akitsuki & Decety, 2009; Singer et al., 2006). Self-regulation can take place at the cognitive level, through strategies such as reappraisal and distraction, as well as at the autonomic level (White et al., 2014). I will focus on autonomic regulation in this thesis. In the next section I will discuss how resting state physiological regulation primes the individual for social engagement and emotion regulation, and what this means for the study of empathy.

Physiological Afferents and Efferents of Empathy

Physiological Mechanisms of Empathy

The perception-action model (Preston & de Waal, 2002) posits that perceiving others' actions or emotion states (via their facial expressions and body language or via abstract representations) automatically and unconsciously activates brain areas responsible for the representation of those actions or states in the observer. This activation leads to activation of motor areas, autonomic arousal and activation of affective states in the observer. There is ample evidence that the perception of emotions or pain in others leads to neuronal activation responsible for perceiving own emotions and pain (Azevedo et al., 2013; Singer et al., 2004; Wicker et al., 2003), as well as the sensorimotor brain areas involved in muscle activation (Avenanti et al., 2005; Marcoux, Michon, Voisin, Lemelin, & Jackson, 2013). In other words, empathy is associated with measurable physiological changes in the central and peripheral nervous systems (Carter et al., 2009). Hence, empathy can be tested by measuring peripheral physiology, and resting state physiological arousal may influence the experience of affective empathy.

Preston and de Waal (2002) speculate that empathy processes likely follow two pathways: A fast, reflexive sub-cortical (and therefore unconscious) pathway leading to affective arousal sharing (affective empathy), and a slower cortical pathway that is responsible for cognitive empathy. Although the activation of empathic pathways happens spontaneously in the observer, it can be regulated: Neuronal activation differs for people who are more similar to us or whom we have stronger affiliations with (Singer et al., 2006) and decreases with increased exposure, such as in the case of physicians perceiving painful stimuli of others (Cheng et al., 2007; Decety, Yang, & Cheng, 2010). These observations have lead researchers to speculate that emotion regulation takes place both at the slower,

cortical level and at the bottom-up level, before affective empathy occurs (Blair, 2011; Decety & Svetlova, 2012). A major focus of this thesis is bottom-up autonomic regulation of empathy.

Autonomic Regulation and Empathy

Empathic concern is not just a dispositional factor, but can change from moment to moment depending on environmental and physiological factors. For example, non-optimal physiological arousal can result in lower motivation to care for another, poorer perception of another's mental state, or high personal distress (Liew et al., 2011; Park & Thayer, 2014; Zahn-Waxler, Cole, Welsh, & Fox, 1995). Imagine, for example, that you are in a shopping centre, you are tired and hungry, and a child in front of you is crying. Though at other times you may feel concern for the child and wish to console it, you may now instead feel mounting distress or annoyance. You may also fail to appropriately perceive the mental state of the child's mother, who may feel embarrassed. Your response in this situation may be very different from that in another situation where you are physiologically in a better position to regulate your own affective responses. Thus the measurement of resting state physiology is an important indicator of the capacity for state affective empathy and concern, cognitive self-regulation, and even cognitive empathy, which is most often thought of as a trait rather than state variable.

This section outlines the argument that baseline autonomic regulation affects our cognitive and affective processes, including our capacity for empathy and our ability to regulate affective states. I will discuss two models linking autonomic regulation to personal and social emotion regulation; namely, the neurovisceral integration model and polyvagal theory. Secondly, I will discuss the evidence that autonomic dysregulation may contribute to the combination of reduced cognitive empathy and self-regulation seen in ASD.

The neurovisceral integration (Thayer & Lane, 2000, 2009) and polyvagal (Porges, 1992, 2001, 2003b) theories propose that the autonomic nervous system plays an integral role in emotional arousal and regulation, as well as flexible responding. The two theories have much in common and share many of their predictions, so they will be discussed together here. To give some background, the autonomic nervous system is divided into two systems that can work cooperatively or antagonistically. The sympathetic nervous system allows orientation to salient stimuli and initiates a 'fight or flight' reaction in response to threatening situations, which includes heart rate acceleration, increased cardiac output and increased skin conductance. The parasympathetic system is active during calm, restful states and digestion, and is associated with heart rate deceleration.

In healthy individuals, both the sympathetic and parasympathetic systems are active at rest so that the individual has sufficient flexibility to respond to any situation. However, the resting state inhibition of heart rate by the parasympathetic system is particularly important for cardiac responsiveness and flexibility (Thayer & Lane, 2000) as parasympathetic arousal has a shorter latency period and wider chronotropic range (Appelhans & Luecken, 2006; Berntson, Cacioppo, Quigley, & Fabro, 1994). High parasympathetic arousal allows efficient energy exchange and cardiac responsiveness (Grossman & Taylor, 2007), and is indicative of the organism's capacity to integrate behavioural and metabolic demands. Chronic sympathetic arousal without appropriate parasympathetic down-regulation is also undesirable as a continuous stress response can lead to sleep disturbances, burnout and chronic fatigue in the long term (Malpas, 2010; Melamed et al., 1999; Wyller, Eriksen, & Malterud, 2009).

The central tenet of the neurovisceral integration theory is the reciprocal connectivity between the heart and the Central Autonomic Network. The Central Autonomic Network, comprising of, among others, the insular cortex, ventromedial prefrontal cortex and the amygdala, is implicated in emotion perception, inhibition and regulation of arousal (Adolphs,

2008; Etkin, Egner, & Kalisch, 2011; Kohn et al., 2014; Wu et al., 2016). The components of the Central Autonomic Network are reciprocally interconnected to the sinoatrial node of the heart via the vagus nerve and stellar ganglia (Benarroch, 1993; Thayer, Hansen, Saus-Rose, & Johnsen, 2009), meaning that the Central Autonomic Network both sends output to and receives input from the autonomic nervous system, so that there are continuous positive and negative feedback loops between these brain areas and the heart (Sakaki et al., 2016; Thayer & Lane, 2000). Dysregulation of vagally-mediated parasympathetic arousal, or cardiac vagal control (also called vagal cardiac tone), can lead to dysregulation at its efferent sites in the Central Autonomic Network, disrupting functioning in the areas related to emotion perception and regulation (e.g., Brosschot, Van Dijk, & Thayer, 2007; Melzig, Weike, Hamm, & Thayer, 2009).

Two predictions from the neurovisceral integration and polyvagal theories are of particular importance to empathy. The neurovisceral integration model stresses the importance of resting state parasympathetic inhibition of the Central Autonomic Network in emotion regulation. As discussed previously, regulation of affective empathy plays a large role in feeling empathic concern for a target and inhibiting personal distress. Whereas the neurovisceral integration model mainly focuses on intra-personal self-regulation and emotions, the polyvagal theory extends the work on self-regulation of emotion to predict social behaviour. The polyvagal theory (Porges, 2003a, 2003b) emphasises that, through vagus nerve efferents to the pharynx, larynx and neck, and connectivity with ventromedial prefrontal cortex areas (Hänsel & von Känel, 2008), cardiac vagal control influences "affective experience, emotional expression, facial gestures, vocal communication, and contingent social behaviour" (Carter et al., 2009, p. 170). In other words, optimal cardiac vagal regulation predicts well-regulated social behaviour. As empathic emotions result from the same physiological processes as self-emotions, the two theories' predictions can be

expanded to affective empathy and its regulation. The predictions that both resting state parasympathetic inhibition of the Central Autonomic Network and changes in cardiac vagal regulation are involved in (1) emotion regulation, and (2) affective experience and social-communicative behaviour, suggest that parasympathetic regulation is critical to the experience of empathy, and in particular the regulatory component of empathy.

Parasympathetic arousal. Parasympathetic regulation is hypothesised to be strongly associated with emotion regulation ability and social engagement. Parasympathetic influence on heart rate, or cardiac vagal control, can be estimated non-invasively by measuring changes in heart rate variability. Heart rate variability reflects the beat-to-beat changes in heart rate associated with respiration (Cacioppo, Tassinary, & Berntson, 2007). High-frequency heart rate variability, or respiratory sinus arrhythmia (RSA), is mainly under parasympathetic control (Grossman & Taylor, 2007), and is associated with a slowing in heart rate[1]. In other words, high RSA is indicative of high parasympathetic arousal and is reflective of the functioning of the Central Autonomic Network (Napadow et al., 2008).

Higher resting state RSA and lower heart rate are associated with greater assertiveness, prosocial emotions, and social competence (Beauchaine, Gatzke-Kopp, & Mead, 2007; Kogan et al., 2014; Kok & Fredrickson, 2010; Stellar, Cohen, Oveis, & Keltner, 2015). Higher resting state RSA is also associated with frequency of social support seeking, self-regulation (Geisler, Kubiak, Siewert, & Weber, 2013), trait agreeableness and positivity (Oveis et al., 2009; Z. Wang, Lü, & Qin, 2013), joint attention, and conventional gestures (Patriquin, Scarpa, Friedman, & Porges, 2013). Furthermore, higher resting state RSA is correlated with better attentional, affective, and behavioural regulation (Butler, Wilhelm, & Gross, 2006; Porges, 1992; Segerstrom & Nes, 2007). The evidence therefore suggests that

[1] RSA does not exclusively indicate vagal tone: RSA is influenced by respiration rate and tidal volume, even under relatively sedentary conditions. RSA is also influenced by beta-sympathetic arousal (Berntson, Cacioppo, & Grossman, 2007; Grossman & Taylor, 2007). However, RSA can be used as an indicator of phasic cardiac vagal control when respiratory factors are controlled.

greater vagally-mediated resting state parasympathetic regulation, or vagal cardiac control, enhances affective regulation and primes the individual for better social interactions.

Despite the literature on resting state RSA and social competence, very few studies have measured the association between RSA and empathy. Given the association between RSA, social engagement and regulation, resting state RSA should also predict the capacity to regulate affective empathy. Thus, high resting state RSA should be associated with higher empathic concern and lower personal distress (as argued in Diamond et al., 2012). In agreement with this hypothesis, an early study found that typically developing girls (though not boys) with high heart rate variability[2] to a neutral stimulus had greater dispositional empathic concern and lower self-reported distress (Fabes et al., 1993). Similarly, high resting state RSA showed a small but significant correlation with empathic concern in neurotypical toddlers (Liew et al., 2011). Others have suggested that resting state RSA may be associated with cognitive empathy: Children with ASD who had higher resting state RSA had better emotion recognition, as well as better conventional gestures, communication, and social skills (Bal et al., 2010; Patriquin, Lorenzi, Scarpa, & Bell, 2014; Vaughan Van Hecke et al., 2009). However, a study of neurotypical mother-adolescent dyads found that resting state RSA only predicted empathic sensitivity (similar to my definition of cognitive empathy, though limited to the perception of affective states) in adolescents with low attachment anxiety (Diamond et al., 2012). A recent set of studies in neurotypical adults also found inconsistent relations between resting state RSA and empathic concern (Stellar et al., 2015). Thus, it is not clear whether a significant association between resting state RSA and empathy exists. Certainly, results from the broader literature suggest that such a link should exist: Reduced resting state RSA is associated with blunting of subjective emotional reactions (Sollers et al., 1997, in Thayer & Lane, 2000) and disruptive behaviour disorder with callous-unemotional traits,

[2] These authors do not specify whether they measured high-frequency heart rate variability. Thus this variability may also be reflective of changes in sympathetic arousal.

where lack of empathy is a defining feature (Beauchaine et al., 2007; de Wied, Boxtel, Matthys, & Meeus, 2011). Clearly, more research on the association between resting state RSA and empathy is needed. The association between empathy and cardiac vagal control may also be more evident during changes in arousal to empathy-inducing stimuli.

Parasympathetic responsiveness, or cardiac vagal reactivity, is also thought to be important for regulating empathy. Cardiac vagal reactivity is hypothesised to reflect attention and effortful emotion regulation (Liew et al., 2011; Porges, 1992). There is strong evidence for RSA withdrawal, or decreases in RSA, during concentration and to stressors such as mental arithmetic tasks (Berntson et al., 1994; Chen, Matthews, Salomon, & Ewart, 2002), and as such, many studies have specifically focused on RSA withdrawal when examining cardiac vagal reactivity (e.g., Muhtadie, Koslov, Akinola, & Mendes, 2015). However, there is inconsistent evidence for the association between RSA reactivity and empathy, or more broadly, social engagement. RSA withdrawal in response to empathy-inducing stimuli has been associated with lower affective displays of concern, and greater distress and freezing responses (Gill & Calkins, 2003; Kreibig, 2010; Liew et al., 2011). Additionally, RSA withdrawal has mostly been associated with reduced social engagement and fewer prosocial behaviours in threatening social environments (Muhtadie et al., 2015; Obradović, Bush, Stamperdahl, Adler, & Boyce, 2010). In keeping with the idea that RSA withdrawal could be an index of greater threat, one study found RSA withdrawal in typically developing children during social interaction with a stranger (a potentially distressing situation), but increasing RSA during interaction with a familiar partner (positive situation; Neuhaus et al., 2015). Similarly, empathic concern to sad empathy-eliciting stimuli is associated with increases in RSA, or RSA augmentation (Hastings & Miller, 2014; Kreibig, 2010). RSA augmentation has also been associated (albeit inconsistently) with verbal and non-verbal expressions of empathic concern (Stellar et al., 2015). Thus, there is tentative evidence of correlations

between RSA withdrawal and distress, as well as with RSA augmentation and feelings of sadness or empathic concern.

Inconsistent findings may be explained by the fact that although the two autonomic systems are both continuously active, studies have often only measured one type of response. It is important to measure the interaction of the two systems to understand elicited emotions (Alkon et al., 2003; Beauchaine et al., 2007; Berntson et al., 1994). For example, non-crying sadness generally corresponds to sympathetic and parasympathetic co-activation, whereas fear corresponds to sympathetic activation with concomitant parasympathetic inhibition (see Kreibig, 2010, for a review). It is critical to examine both parasympathetic and sympathetic contributions to autonomic function when measuring physiological reactivity. With this in mind, I turn to a discussion of the behavioural and affective correlates of sympathetic arousal.

Sympathetic arousal. The main focus in studies of autonomic regulation of behaviour, affect and cognition has been the parasympathetic system. However, as discussed in the previous section, this system works in conjunction with the sympathetic system. Inconsistencies in autonomic arousal findings may partly be due to studying only one half of the regulation that occurs at any one time, as well as from neglecting to separate sympathetic from parasympathetic influences. For example, RSA augmentation is not only associated with concern, but also with externalising behaviours in children (Hinnant & El-Sheikh, 2009). However, this association changes when taking sympathetic activity into account: Increased cardiac vagal control in the presence of increased sympathetic activity to stressors (i.e., autonomic co-activation) is associated with lower family conflict and child conduct problems (Salomon, Matthews, & Allen, 2000). Thus, in predicting social functioning, it is critical to study the interaction between the autonomic branches.

Until fairly recently sympathetic arousal has been hard to study, because the most convenient measures of arousal, skin conductance, and heart rate are influenced by both nervous systems and are not pure measures of sympathetic arousal. Hence sympathetic regulation, and its role in empathy, has received much less attention than parasympathetic regulation. New non-invasive techniques to study cardiac sympathetic activity, such as measurement of the pre-ejection period (PEP), make it possible to study both sympathetic and parasympathetic influences on the heart. The pre-ejection period is a relatively pure measure of beta-adrenergic sympathetic arousal, or cardiac sympathetic activity. It is defined as the time, in milliseconds, from cardiac electrical depolarisation to the time when the aortic valve opens and blood is expelled from the ventricle (Cacioppo et al., 2007). The more sympathetic activation there is, the faster the time to contraction, and the shorter the pre-ejection period. Measurement of the pre-ejection period thus allows the study of the relationship between empathy and cardiac sympathetic activity.

Sympathetic activity is most clearly linked to feeling of anxiety and distress, with a tentative link between heightened sympathetic arousal and lower empathy. Early research found associations between increases in heart rate to challenge and feelings of personal distress and anxiety (Eisenberg et al., 1989). More recent research examining pre-ejection period reactivity has found positive correlations between sympathetic reactivity and social-evaluative stress (Berntson et al., 1994). For example, sympathetic reactivity was positively correlated with self-reported shame in neurotypical adults during a negative feedback social stress task (Muhtadie et al., 2015). A recent study found a correlation between higher baseline skin conductance (indicative of greater sympathetic arousal) and poorer self-reported affective and cognitive empathy in neurotypical adults (Mathersul, McDonald, & Rushby, 2013). Similarly, Neuhaus et al. (2015), who measured pre-ejection period reactivity and

parent-report social skills in children with and without ASD, found a negative correlation between sympathetic arousal and social skills.

Not all research supports the link between high sympathetic reactivity and reduced empathy: A study on empathy found that higher skin conductance responses were related to helping others at a later time, even if that came at some cost to the individual (Hein, Lamm, Brodbeck, & Singer, 2011). Furthermore, psychopathology research indicates that too little sympathetic arousal to others' distress is detrimental to empathic concern. Attenuated sympathetic responses to stimuli are implicated in social and behavioural maladjustment (Stifter, Dollar, & Cipriano, 2011), conduct disorder (Beauchaine et al., 2007; Marsh, Beauchaine, & Williams, 2008) and psychopathy (van Goozen, Fairchild, Snoek, & Harold, 2007). In summary, some sympathetic response – neither too much nor too little – may be optimal for empathy and social engagement. Whereas reciprocal sympathetic arousal (i.e., sympathetic activation and parasympathetic inhibition) may occur during greatest threat (Alkon et al., 2003), autonomic co-activation, in other words, increases in sympathetic activity accompanied by increases in parasympathetic activity, may best predict prosocial behaviour (Salomon et al., 2000). Autonomic co-activation may prevent unchecked fight-or-flight responses and best predict empathic concern.

These studies create a strong argument for studying sympathetic and parasympathetic arousal at the same time. Understanding the interaction of these two systems can shed light on how patterns of autonomic arousal during attention-demanding or challenging states facilitate different forms of empathy. Next I discuss what is known about resting state parasympathetic and sympathetic arousal, as well as autonomic reactivity to empathy-related stimuli in ASD, before turning to some caveats of the polyvagal theory.

Autonomic regulation and ASD. Some studies have found that parasympathetic arousal is reduced at rest in ASD (Althaus et al., 2004; Cohen, Masyn, Mastergeorge, & Hessl, 2015; Matsushima et al., 2016). However, results are mixed, and a recent review article concluded that resting state RSA is not affected in ASD (Benevides & Lane, 2015). Even if ASD is not associated with changes in resting state arousal in general, those individuals with higher cardiac vagal control may show better social functioning. Several studies have found that children with ASD with higher baseline RSA have better emotion recognition, conventional gestures, communication and social skills (Bal et al., 2010; Patriquin et al., 2014; Sheinkopf, Neal-Beevers, Levine, Miller-Loncar, & Lester, 2013; Vaughan Van Hecke et al., 2009).

There is also some evidence, albeit inconsistent, of atypical autonomic regulation in ASD during social tasks. As discussed previously, two studies have found evidence of reduced parasympathetic (Vaughan Van Hecke et al., 2009) and heightened sympathetic arousal (Neuhaus et al., 2015) to strangers, indicating a heightened perception of threat and initiation of fight-or-flight responses in ASD. Neuhaus et al. (2015) showed that boys with ASD did not differentiate between novel and familiar social situations in their autonomic response, whereas typically developing boys did. In agreement with the greater distress response, two studies have found evidence for heightened (predominantly sympathetic) reactivity to direct eye gaze in children with ASD (Kylliäinen et al., 2012; Kylliäinen & Hietanen, 2006), and other studies have found greater neural activation or diminished habituation of skin conductance responses to human faces (Dalton et al., 2005; Mathersul et al., 2013). These results suggest that the physiological regulation of affect may be atypical in ASD. However, other studies have found no difference in sympathetic or parasympathetic responses to social stress (Hollocks, Howlin, Papadopoulos, Khondoker, & Simonoff, 2014; Levine et al., 2012; Sheinkopf et al., 2013), or have even found social-specific hypoarousal

(Hirstein, Iversen, & Ramachandran, 2001; Hubert, Wicker, Monfardini, & Deruelle, 2009) in ASD. The inconsistency of the findings suggest that rather than differences in absolute levels of arousal, individuals with ASD may have less flexible responding, as was found in Neuhaus and colleagues' study. A difficulty in interpreting many of these studies is that stimuli vary widely, and have often not been validated in other studies. Thus, Chapter 3 discusses performance on one specific well-validated paradigm for empathy; empathy for pain.

Summary. The sympathetic and parasympathetic divisions of the autonomic nervous system can work cooperatively or antagonistically. The sympathetic nervous system is responsible for orienting the organism to salient stimuli and initiates a 'fight or flight' reaction, whereas the parasympathetic system is associated with calm, restful states, and is normally active during social engagement. The neurovisceral integration model (Thayer & Lane, 2000, 2009) and polyvagal theory (Porges, 1992, 2001, 2003b) propose that the autonomic nervous system is essential for emotion arousal and regulation, as well as flexible responding. The autonomic nervous system affects, and is affected by, central nervous system activity through the vagus nerve. Dysregulation of vagally-mediated parasympathetic arousal, or cardiac vagal control, is therefore predicted to lead to disrupted emotion perception and regulation, as well diminished empathy.

In support of the two theories, high resting state parasympathetic arousal is associated with better emotion regulation, increased prosocial and positive emotions, and better social competence (including more support-seeking, using more gestures, and better joint attention). Evidence for an association between resting state cardiac vagal control and empathic concern is inconsistent at best; however, there is evidence of an association between parasympathetic regulation, or vagal flexibility, and empathy: Cardiac vagal control is heightened during empathic concern, whereas reductions in cardiac vagal control from rest are associated with

personal distress. Parasympathetic regulation is thus thought to represent active emotion regulation. In contrast with parasympathetic arousal, heightened sympathetic arousal is correlated with feelings of anxiety and distress, and lower empathic concern. However, some sympathetic arousal is important to notice others' distress, and thus co-activation of the sympathetic and parasympathetic branches is proposed to be the optimal response to others' distress or pain. In ASD, there may be less flexible regulation of these two branches of the autonomic system, potentially associated with atypical subjective affective responses and social functioning.

There are, however, some caveats to the interpretation of RSA. Likewise, some of the assumptions of the polyvagal theory have been criticised. I briefly review the flaws in previous cardiac vagal control research designs before turning to suggestions for improvement in Chapter 3.

Critique of the Polyvagal Theory

Although the neurovisceral integration model is largely an extension of the polyvagal theory, there are some important differences. A primary assumption of the polyvagal theory is that there are two evolutionary and functionally distinct sets of brainstem nuclei controlling heart rate: One that is responsible for fast respiratory-related changes in heart rate (i.e., RSA) in mammals and influences social behaviour and communication, as well as one that controls subdiaphramatic visceral organs and behaviour immobilisation (Porges, 2003b) and does not influence RSA. There is currently no way to separate the influence on the heart of one set of nuclei from the other (Berntson, Cacioppo, & Grossman, 2007), and neither is there evidence that RSA is only present in mammals; thus, the current thesis follows the example of the neurovisceral integration model, and will not speculate on any functional differences between vagal nuclei.

The polyvagal theory has also been heavily criticised on several other grounds. The first criticism, which is that under rare circumstances RSA and cardiac vagal control are not associated with each other, does not directly affect this study. Such a dissociation has only been shown under extreme events such as during pharmacological augmentation of the cardiac baroreflex or during experimentally-induced changes in respiration by stimulation of carbon dioxide receptors (Grossman & Taylor, 2007). These methods will not be used within the current studies, and RSA will only be measured within the range of normal functioning.

Secondly, several factors other than cardiac vagal control can affect RSA. Respiration, physical activity and beta-adrenergic sympathetic tone influence RSA and potentially confound the association between RSA and cardiac vagal control. Both respiration rate and volume can substantially influence RSA magnitude, even when participants are stationary. Similarly, even relatively small changes in sympathetic activity can lead to large reductions in RSA, either because of suppression effects or because of interactions between the sympathetic and vagal systems (Grossman & Taylor, 2007; Kollai & Mizsei, 1990). These factors must be measured and controlled for when using RSA as a measure of phasic vagal cardiac control.

Thirdly, although within-subject correlations between RSA and cardiac vagal control are generally strong, the association between these variables can be weak between subjects as there are many different processes which affect cardiac vagal control. Between-subject associations may therefore not be identifiable in typical between-group research designs (Berntson et al., 2007; Grossman & Taylor, 2007). Measuring within-person changes over time, rather than between-groups differences, therefore provides a more accurate indicator of cardiac vagal control.

In sum, there are several methodological limitations to current RSA research, and these need to be addressed when studying the autonomic correlates of empathy. However, if individual differences between participants and respiratory factors are taken into account, RSA can be a reliable indicator of cardiac vagal control, and, as postulated by the polyvagal theory, social engagement.

Conclusion

Autism is characterised by a spectrum of deficits in social-communicative behaviour. In this chapter I have argued that the social impairments in ASD are likely not due to a global deficit in empathy, as has previously been suggested. Empathy is not a unitary concept, but is an umbrella term defining several different abilities which can be separately affected. Although cognitive empathy is impaired in ASD, the sharing of other's emotions, or affective empathy, may be intact. However, poor regulation of affective empathy may lead to high levels of distress and fluctuating, often reduced, levels of empathic concern and prosocial behaviour in ASD. Poor regulation at the autonomic level may contribute towards the deficits in affect regulation and social engagement seen in ASD. To best describe the empathic profile of ASD, studies should take a multilevel approach, examining empathy at, among others, the physiological, cognitive and subjective levels.

In the next chapter I introduce the specific paradigm in which empathy was studied in this thesis; namely empathy for pain. I review the typical autonomic, muscular and subjective responses to observing others in pain, and what the study of these responses can tell us about the profile of empathy deficits in ASD.

CHAPTER 3.

EMPATHY FOR PAIN

"pain insists upon being attended to" (Lewis, 1940)

Perception of pain is a well-validated paradigm in which to study empathy. The ability to perceive and react swiftly to others' pain is essential to survival. Accordingly, images of others' pain are extremely salient: Facial expressions of pain are perceived as more arousing and more unpleasant than other emotions of similar arousal levels (Simon et al., 2008), and are processed in a more sustained fashion than other facial expressions (Reicherts et al., 2012). Observation of others' physical pain evokes even larger reactions than do facial expressions of pain (Vachon-Presseau et al., 2011), and elicits strong empathic responses from participants, making this paradigm ideal to study the different components of empathy. Empathy for pain has mostly been studied from a neural perspective, with less attention given to peripheral responses to observed pain. This chapter summarises what is known about autonomic, muscular and affective reactivity to observed pain. I will discuss the typical autonomic and muscle responses associated with empathic concern or personal distress, and then review the results of studies of empathy for pain in ASD. I end with a discussion of the aims and hypotheses of this thesis.

Affective and Physiological Responses to Perceived Pain

The perception of pain in others activates affective brain areas responsible for perceiving self-pain (Bird et al., 2010; Singer et al., 2004) and rapidly elicits defensive reactions characterised by decreases in heart rate and increases in skin conductance (Lamm, Porges,

Cacioppo, & Decety, 2008; Lanzetta & Englis, 1989). Under non-threatening conditions, this initial and automatic affect sharing is quickly down-regulated (Han, Fan, & Mao, 2008). This down-regulation is thought to assist empathic concern, rather than a pure distress response to witnessing pain. Studies of event-related potentials to observed pain show evidence that the initial affective response and secondary evaluation are separate; occurring in different neural areas and at different times (Y. Fan & Han, 2008). Parasympathetic activation may assist down-regulation by moderating the initial affective response: Studies have found that children who respond with greater heart rate deceleration – potentially led by increases in parasympathetic regulation - show more prosocial behaviour, whereas children who show higher skin conductance responses show less prosocial behaviour (see Eisenberg et al., 2010 for a review). Given the importance of cardiac vagal control in emotion regulation, it is surprising that so far only one study has looked at parasympathetic reactivity to others' pain. As expected, this study found evidence for increases in RSA when perceiving others in pain (Lepron, Causse, & Farrer, 2015). These results correspond to findings of RSA augmentation during empathic concern for others' distress (Stellar et al., 2015), but need to be replicated under different conditions of pain.

Cognitive processes modulate the magnitude of the affective downregulation response (Y. Fan & Han, 2008; Li & Han, 2010); for example, participants display greater affective responses to confederates who show greater fairness to others (Singer et al., 2006). Likewise, switching perspectives from imagining how the other person feels to imagining how you would feel increases affective arousal, particularly personal distress (Lamm et al., 2008; Li & Han, 2010). On the other hand, alexithymia is associated with reduced neural responses to viewing others' pain and lower estimates of the pain intensity (Bird et al., 2010; Moriguchi et al., 2007). Thus, though the initial affective response does not seem to depend on cognitive empathy (Y. Fan & Han, 2008), the ability to understand and describe mental states may

modulate the extent of the ultimate affective response. Particularly, greater identification with the target and greater understanding of own emotions leads to greater affective responses. Cognitive regulation may also influence muscle responses to observed pain.

Muscle Responses to Observed Pain

Two predictions for muscle reactivity to others' pain have been put forth. One prediction is that of an automatic freezing reaction to avoid possible harm (Avenanti, Minio-Paluello, Sforza, & Aglioti, 2009). Recent research has focused predominantly on this prediction, through the study of corticospinal inhibition of muscle-evoked potentials (Avenanti, Paluello, Bufalari, & Aglioti, 2006; Avenanti, Sirigu, & Aglioti, 2010; Minio-Paluello, Baron-Cohen, Avenanti, Walsh, & Aglioti, 2009). These authors have found that participants show diminished motor-evoked potentials specific to the area of the muscle observed to be hurt (Avenanti et al., 2006). Additionally, individuals with higher cognitive empathy show greater corticospinal inhibition (Avenanti, Minio-Paluello, Bufalari, & Aglioti, 2009). However, not all studies have found such an inhibition response: Increased identification with the target, either by having the observer imagine themselves in the other's position or by having the target imitate the observer's movements, seems to lead to *increased* muscle-evoked potentials (de Coster, Andres, & Brass, 2014) and muscle activation (Lamm et al., 2008; Sonnby-Borgström, Jönsson, & Svensson, 2003; Sun, Wang, Wang, & Luo, 2015), as is also observed in participants' subjective and neural responses. These results are more consistent with unconscious muscle mimicry of the target, similar to the muscle mimicry seen for non-pain expressions. Corresponding to this hypothesis, studies have reported increased reactivity to others' pain in the muscles responsible for orbit tightening and furrowing the brow (Caes et al., 2012; Lamm et al., 2008; Lanzetta & Englis, 1989). Furthermore, there is evidence that such muscle reactivity is not purely an automatic avoidance response, because muscle reactivity increases with an observer's sense of

responsibility for the pain (Lepron et al., 2015), and differs depending on the social context, including whether the target is cooperating or competing with the observer (Lanzetta & Englis, 1989). Moreover, pain-induced muscle flexion reflexes when observing others' pain (Vachon-Presseau et al., 2011) and facial mimicry of basic emotions have been correlated with trait empathy (e.g., Dimberg & Thunberg, 2012; Sonnby-Borgström et al., 2003). Increased communicative opportunity also predicts greater muscle reactivity (Bavelas, Black, Lemery, & Mullett, 1986). Hence, rather than being an avoidance response, muscle reactivity seems to be part of an overall empathy response. In particular, Bavelas and colleagues (1986) propose that muscle reactivity to pain has a communicative function, indicating concern for the person being hurt, and facilitating social cohesion.

On the whole, neurotypical individuals show an involuntary and unconscious response to seeing others' pain. Neural areas involved in own-pain perception are activated; at the autonomic level, empathic concern is associated with the co-activation of the sympathetic and parasympathetic nervous systems; and at the muscular level, individuals may show mimicry of others' pain. Though this response is automatic, it is not indiscriminate: Cognitive empathy and alexithymia, among other factors, determine the scale of the affective response. These factors also modulate empathic responses in ASD.

Empathy for Pain in ASD

Empathy for pain in ASD has only recently gained attention, and has focused on empathy for others' physical pain. An early study examining motor-evoked potentials found reduced corticospinal inhibition to others' pain in ASD (Minio-Paluello, Baron-Cohen, et al., 2009). The authors of this study attributed the reduced inhibition to reduced affective empathy, or mirroring of pain, in ASD. However, subsequent studies of neural and autonomic reactivity in ASD have found contrasting results: Participants with ASD perceive a target's

pain as equally intense as participants without ASD once alexithymia is controlled for (Bird et al., 2010). Furthermore, when asked to engage with empathy-for pain-stimuli, individuals with ASD personally experience a target's pain as *more unpleasant* than neurotypical individuals do (Gu et al., 2015). These results suggest that ASD individuals do experience automatic affect sharing, but fail to down-regulate their response. Diminished regulation of arousal could be due to reduced cognitive empathy, reduced cognitive self-regulation, or atypical physiological regulation in ASD. In evidence of the reduced regulation argument, participants with ASD show similar or heightened skin conductance and startle reflex responses, and diminished fronto-insular cortex inhibition, during observation of a target's pain compared to neurotypical adults (Y.-T. Fan et al., 2014; Gu et al., 2015; Hadjikhani et al., 2014). Individuals with ASD also show decreased ability to discriminate between painful and non-painful conditions, in keeping with diminished cognitive empathy in this group. Minio-Paluello and colleagues' (2009) finding of reduced inhibition may thus be better explained by an impairment in regulation of affective (corticospinal) responses to pain, rather than an impairment in affective empathy. What is not known is whether these results are limited to seeing the pain being inflicted (i.e., empathy for physical pain), as was investigated in the studies above, or whether it extends to feeling empathy for others' expressions of pain.

In sum, empathy for pain is characterised by an initial and involuntary affect sharing, which is quickly down-regulated under optimal conditions to lead to empathic concern. Dispositional cognitive empathy, perspective-taking, autonomic regulation, and the ability to understand one's own emotions may all facilitate this down-regulation. In ASD, there is tentative evidence of reduced self-regulation of affective responses, so that subjective distress, distress-related autonomic arousal (i.e., increased sympathetic arousal and/or decreased parasympathetic arousal), and muscle activity may be expected to be heightened when observing others' pain. Moreover, if affective empathy is not efficiently regulated in

individuals with high amounts of autism traits, empathic concern for others may be reduced. Studies have also found decreased ability to discriminate between painful and non-painful states in participants with high amounts of autism traits, though this may partly be attributable to alexithymia. In individuals with alexithymia, both affective empathy and empathic concern can be expected to be reduced.

Rationale

I have presented evidence that affective empathy appears to be intact in ASD, and that general emotion regulation is impaired. Social-communicative deficits in ASD may stem not from a general deficit in empathy, but from deficits in cognitive empathy paired with deficits in regulation of affective empathy. However, to my knowledge, no study has looked at the autonomic contributions to the regulation of empathy within ASD. It is clear that physiological regulation of affective responses is critical in determining whether responses are predominantly other-focused (empathic concern) or self-focused (personal distress) in nature. Furthermore, studies that have investigated the associations between autonomic regulation and empathy, or autonomic regulation and social engagement, have for the most part only investigated either parasympathetic or sympathetic arousal, not both. Yet the reviewed literature creates a strong argument for studying sympathetic and parasympathetic arousal at the same time. A novel contribution of this thesis is that sympathetic and parasympathetic reactivity to empathy-inducing stimuli was measured concurrently. This allows the modelling of the interaction between the two systems and their association with empathic concern.

Furthermore, the limited empathy-for-pain studies that have been done in ASD have only used stimuli featuring direct pain application, such as seeing a body part being injured. However, humans also have the capacity to feel empathy for others showing signs of distress,

even if the painful incident was not observed. It is therefore also very important to study empathy for distress signals of pain (e.g., facial expressions of pain) in autism. Many individuals with autism have difficulties in interpreting facial expressions, in particular rapid and dynamic facial expressions (Clark, Winkielman, & McIntosh, 2008; Sato, Uono, & Toichi, 2013), and other non-verbal communications (e.g., Bedford et al., 2012; Boria et al., 2009; Vivanti et al., 2011). Moreover, individuals with ASD may be slower to spontaneously mimic facial expressions (Oberman et al., 2009). Thus individuals with ASD may not have the same responses to viewing facial expressions of pain as to viewing sensory pain, and may have slower reactions to facial expression of pain than neurotypical individuals do. Accordingly, this thesis investigates both empathic responses to perception of physical pain and perception of facial expressions of pain.

Finally, this thesis improves on the methodology of autonomic arousal measurement and analysis. Previous research measuring RSA has been criticised for not controlling for factors that influence RSA but are not reflective of cardiac vagal control, such as respiration, physical activity and beta-adrenergic sympathetic arousal. Furthermore, researchers have argued that the correlation between RSA and cardiac vagal control may not be identifiable in a between-groups design (Berntson et al., 2007; Grossman & Taylor, 2007). This thesis addresses the flaws in previous research by (1) using a research design where participants remain stationary while stimuli are shown, (2) measuring and statistically controlling for respiration rate and volume and beta-adrenergic sympathetic activity, and (3) employing mixed-effects model analyses whereby individual (within-subject) differences can be statistically modelled. A further strength of this thesis is that it follows a dimensional and multilevel approach to studying empathy and ASD; the reasons for which are outlined below.

A Dimensional, Multilevel Approach to Studying ASD

As discussed in Chapter 2, the core features of autism are normally distributed in the population, and are not specific to autism. Additionally, within the DSM-5 category ASD there is remarkable heterogeneity of both symptom presentation and symptom severity (London, 2014; Pinto et al., 2014). Yet there is a paucity of research examining features of autism and their associated biopsychological processes at different levels of severity. Most research still operates within the traditional paradigm of comparing different diagnostic categories, or comparing members of a diagnostic category to a healthy control group. However, the problem with the traditional approach is that overlaps in symptoms between groups reduces the statistical power to detect between-group differences, and furthermore, even if statistical power is sufficient, it is unlikely that there is a single biopsychological pathway leading to a specific disorder (Cuthbert, 2014; Kozak & Cuthbert, 2016). This is particularly true in ASD, where many researchers have argued that we should use the term 'the autisms' or 'autism spectrum disorders' to recognise that all individuals with ASD do not necessarily share the same symptoms, outcomes, or underlying causes of the disorder (Geschwind & Levitt, 2007). This thesis aims to address the problem by taking a dimensional approach to the study of autism and empathy. The Research Domain Criteria (RDoC) is such an approach to studying psychiatric conditions.

In 2008, the United States National Institute of Mental Health brought in the RDoC project in recognition of the fact that the study of the traditional DSM psychiatric categories has not led to major advances in understanding the underlying biological mechanisms of these conditions. Part of the problem is that an arbitrary number of symptoms are needed to qualify for diagnosis, meaning that (1) different individuals with the same disorder may have very different behavioural and cognitive presentations (and presumably also different genetic and social causes), (2) there can be considerable symptom overlap between different

diagnostic conditions, for example between ASD and obsessive-compulsive disorder or specific language impairment, and (3) severity of a disorder or its symptoms is not accounted for in an all-or-none categorical system. Thus, the goal of the RDoC project is to use dimensions of functioning that cut across traditional diagnostic boundaries, and to measure constructs that are fine-grained enough to map onto psychobiological bases (Cuthbert, 2014).

The RDoC approach is to study process constructs within a continuum of behaviour, from typical to atypical, in order to enhance understanding of the causes, diagnosis, prevention, and treatment of mental disorders (MacNamara & Phan, 2016). Core features of the RDoC approach are that it encourages dimensional measurement and analysis of constructs, and that construct measurement should ideally be at multiple levels of trait conceptualisation; for example, at the neural, physiological and self-report levels. This approach will hopefully lead to more reliable and valid measures of psychological processes.

In accordance with the RDoC approach, this thesis discusses and measures empathy and ASD in a dimensional way, and explores these concepts at several levels of analysis; particularly, the physiological, cognitive and self-report levels. By using different levels of analyses, and a clear definition of empathy that conforms to our biological understanding of its origin and function, this thesis will improve the reliability of empathy measurement in ASD.

Overview of the Studies

Study 1 tests the hypothesis that trait levels of cognitive empathy and self-regulation are negatively correlated with autism traits, while affective empathy is not correlated with autism. Trait levels of the different facets of empathy, alexithymia, and autism are measured via self-report. Furthermore, cognitive empathy is measured with two cognitive tasks, a dynamic emotion recognition task and a social faux pas recognition task. To my knowledge,

this is the first study to examine empathy in ASD from the perspective of three facets of empathy (affective, cognitive, self-regulation) that may be independently affected. Furthermore, many previous studies of empathy in ASD are difficult to interpret because they did not control for the effect of alexithymia on empathy. Thus alexithymia is used as a co-variate in all analyses.

Of course, there are limitations to measuring empathy purely on the basis of self-report. Lack of emotion awareness, heightened social desirability, language comprehension, and other factors may influence responses. Thus Studies 2 and 3 investigate physiological reactions to empathy-induction, specifically autonomic arousal and muscle mimicry, and correlate these with self-reported dispositional and state empathy and empathic concern. Monitoring physiology serves two goals: It provides information on affective responses that are not otherwise observable; secondly, it describes a potential causal mechanism for deficits in empathy. Though the aim of this thesis is not to test the causes of empathy, describing the physiological profile associated with good empathic skills leads the way to more mechanistic studies.

Specific Aims and Hypotheses

The aim of this thesis is to investigate the extent to which state and trait levels of empathy (affective, cognitive and self-regulation) are associated with ASD traits, to describe the physiological processes occurring during an empathy-inducing situation, and to predict the magnitude of the empathic response from resting state autonomic regulation. I investigated whether the magnitude of autonomic and muscular responses is correlated with the amount of autism spectrum traits, and whether there is evidence that abnormal autonomic regulation is associated with autism traits. In particular, I focused on empathy for pain. Because of the importance of pain perception to survival, perceiving the pain of others

reliably elicits robust empathic responses (e.g., Craig, Versloot, Goubert, Vervoort, & Crombez, 2010; Lamm, Decety, & Singer, 2011; Reicherts et al., 2012; Singer et al., 2004). I investigated empathy for two types of stimuli: empathy for sensory pain (Study 2) and empathy for facial expressions of pain (Study 3).

Research Questions

1. To what extent are the trait levels of the different facets of empathy (affective, cognitive, self-regulation) associated with ASD? (Study 1)
2. Is there evidence of resting state autonomic dysregulation in ASD? (Studies 2 & 3)
3. Is resting state autonomic regulation correlated with trait affective, cognitive and self-regulatory empathy? (Studies 2 & 3)
4. Are physiological (muscle and autonomic reactivity) and subjective (pain perception) indices of affective empathy and empathic concern correlated with amount of autism traits?
    a. When observing sensory pain (Study 2)
    b. When observing facial expressions of pain (Study 3)
5. If not, what other factors are correlated with empathic concern (versus personal distress)?
    a. When observing sensory pain (Study 2)
    b. When observing facial expressions of pain (Study 3)

Hypotheses

Study 1: Trait empathy in ASD

To what extent are the trait levels of the different facets of empathy (affective, cognitive, self-regulation) associated with amount of autism traits?

Hypothesis I: Amount of autism traits will be negatively correlated with trait cognitive empathy and self-regulation, even after alexithymia is controlled for. Amount of autism traits will not be correlated with trait affective empathy once alexithymia is controlled for.

Hypothesis II: Amount of autism traits will be negatively correlated with performance cognitive empathy.

Study 2: Empathy for sensory pain & Study 3: Empathy for facial expressions of pain

Is there evidence of resting state autonomic dysregulation in participants with greater autism traits? Is resting state autonomic activity associated with empathy?

Hypothesis III: Higher resting state parasympathetic arousal (vagal cardiac control) will be associated with higher trait affective empathy and self-regulation scores.

Are physiological (muscle and autonomic reactivity) and subjective (pain perception) indices of affective empathy and empathic concern correlated with amount of autism traits?

Hypothesis IV: Pain perception (unpleasantness and intensity) will be positively correlated with amount of autism traits once alexithymia is controlled for.

Hypothesis V: Amount of autism traits will be negatively correlated with empathic concern and positively correlated with personal distress.

Hypothesis VI: Amount of autism traits will be positively correlated with muscle activity.

Hypothesis VII: Amount of autism traits will be positively correlated with sympathetic reactivity and/or negatively correlated with parasympathetic reactivity, resulting in hyperarousal.

What other factors (dispositional and physiological) are associated with pain perception and empathic concern (versus personal distress)?

Hypothesis VIII: Self-regulation scores will be positively correlated with empathic concern and negatively correlated with perception of pain and personal distress.

Hypothesis IX: Cognitive empathy will be positively correlated with empathic concern and perceived pain.

Hypothesis X: Higher resting state parasympathetic arousal (vagal cardiac control) will be associated with increased state empathic concern, whereas higher baseline sympathetic arousal will be associated with increased personal distress.

Hypothesis XI: Poorer self-regulation and cognitive empathy will be associated with increased muscle reactivity.

Hypothesis XII: Increased empathic concern and better self-regulation will be associated with increased parasympathetic reactivity and potentially increased sympathetic reactivity (autonomic co-activation).

CHAPTER 4.

GENERAL METHODS

Participant characteristics and methods applicable to all three studies are described in this chapter. Stimuli and procedures unique to each study are described in Chapters 5 to 7.

Participants

Individuals with and without ASD were invited to participate. Participants were recruited from existing ASD participant databases, support groups, through advertisements on websites, in local newspapers and via the university network, and through the UCT Department of Psychology's Student Research Participation Programme (SRPP). The recruitment and inclusion flowchart is shown in Figure 1. Individuals were invited to participate if they were between 14 and 45 years old and fluent in English. This age range was chosen because physiological reactions change before puberty and after menopause. Participants (N = 841) were first screened on the Autism Spectrum Questionnaire (AQ) and a demographic questionnaire asking about mental and physical health. Those who completed the AQ and who did not report any psychiatric or neurological conditions besides ASD formed the total online sample (N = 519; this sample contained neurotypical and ASD participants).

Based on an a priori power analysis for the level 1 (between-subjects) and level 2 (within-subjects) predictors done with G*Power 3.1 (Faul, Erdfelder, Buchner, & Lang, 2009), a subsample from the total online sample was selected to participate in the empathy for pain and cognitive empathy assessments. The aim of this study was not to compare a diagnosed ASD group with a neurotypical group, but to recruit participants at different levels of the autism spectrum continuum, ranging from no to high ASD traits. The AQ was used to

identify individual differences in autism traits as the questionnaire has good discriminative validity (Woodbury-Smith, Robinson, Wheelwright, & Baron-Cohen, 2005). Additionally, scores on this questionnaire has been shown to be normally distributed in the population (Hoekstra, Bartels, Cath, & Boomsma, 2008). From the online group, all participants who scored over a threshold of 32 points on the AQ (high likelihood of ASD) and who did not report any history of cardiovascular disorder were invited to participate in the laboratory-section of the study. The high autism trait individuals who agreed to participate were each case-matched with a low and a medium-autism-trait individual on age, sex, and race. The closest low and medium-trait matches were invited to participate in the study. Where there were multiple exact matches who all met the inclusion criteria, participants were randomly selected, and the next-best match was invited if the first match declined to participate. In this way, participants with a range of autism traits were recruited. Participants with high autism traits had social-communication deficits and restricted, repetitive or stereotyped behaviours that typically met diagnostic criteria for ASD and impacted on daily functioning. Medium-autism-trait individuals had some features of ASD, such as difficulties with maintaining conversations or peer relationships and inflexibility of behaviour or thoughts, but did not meet criteria for ASD. Low-autism-trait individuals did not have psychiatric diagnoses and had minimal or no features of ASD.

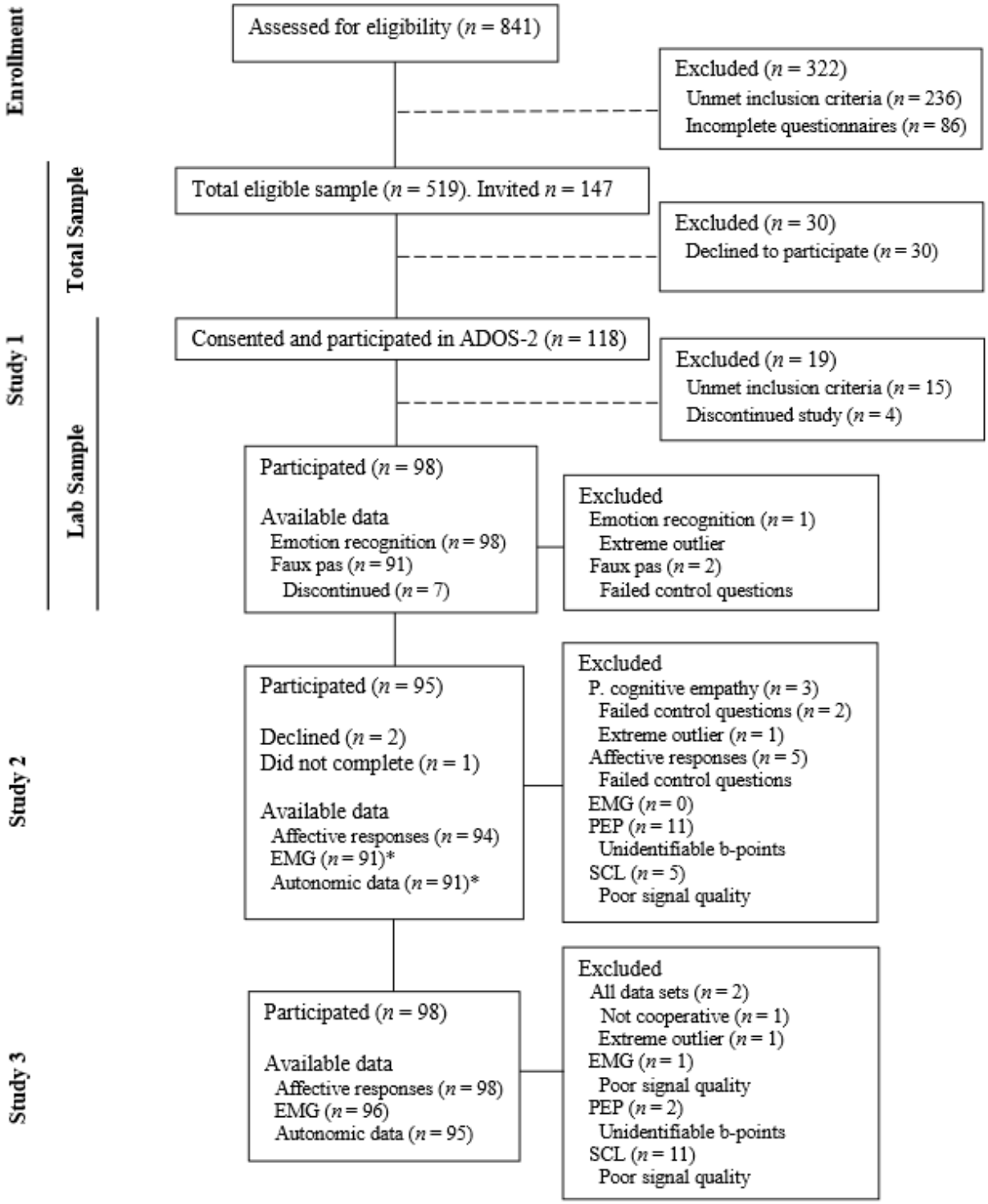

Figure 1. Participant recruitment flowchart. P. cognitive empathy = performance cognitive empathy, EMG = electromyogram, PEP = pre-ejection period, SCL = skin conductance level. * Data are missing due to technical problems.

In total, 147 individuals were invited to participate. Potential participants were excluded if they had a cardiovascular disorder, were currently taking cardiovascular medication (e.g., beta-blockers), or had an acute medical condition that could influence cardiovascular function. In addition, neurotypical candidates were excluded from the study if they had any previously diagnosed neurological or psychiatric disorders.

All participants in the laboratory sample received an Autism Diagnostic Observation Schedule (ADOS-2) assessment to calculate their amount of autism traits. Of the respondents who were invited to participate in the lab-based part of the study, 30 declined, 15 were excluded after the ADOS-2 assessment because of suspected psychiatric or heart conditions which were not originally reported, and 7 did not complete the laboratory session. Ninety-eight participants (79 males) between the ages of 14 and 45 therefore formed the laboratory sample, of which 21 met criteria for ASD on the ADOS-2. The same individuals participated in Studies 1 to 3. However, three participants who completed Studies 1 and 3 did not complete Study 2 (N = 95).

The racial composition of the total sample was 47% White, 27% Black, 14% Mixed-Race, 8% Indian and 3% Other. The racial composition of the laboratory sample was 63% White, 14% Black, 14% Mixed-Race and 8% Indian. The racial composition between the two samples differed because of an over-representation of autism traits in some groups (White) and an under-representation of autism traits in others (Black and Other).

Ethical Considerations

The study followed the Declaration of Helsinki's ethical guidelines for research with human subjects, as well as the guidelines of the Health Professions Council of South Africa, and the University of Cape Town. The study had approval from the Department of Psychology (see Appendix A) and from the Department of Student Affairs (Appendix B) at

the University of Cape Town to advertise on campus. Additionally, approval was obtained from the Western Cape Education Department to recruit participants from public schools in Cape Town (Appendix C). Written informed consent was obtained electronically beforehand (Appendix D). For underage participants (14 – 17 years), informed consent was obtained from parents beforehand and informed assent (Appendix E) was obtained on the day of testing. The study was explained verbally and in writing and participants were given the chance to ask questions about the study and view the recording equipment and laboratory space before they consented to participation. Every effort was made to ensure that participants understood the task demands and the potential benefits and risks of the study.

Participants were reassured that all information would be kept confidential and would only be used for research purposes. To restrict access to sensitive information, all data from the behavioural and psychophysiological assessments have been kept strictly confidential. Participant data were recorded electronically and stored on password-protected servers at the University of Cape Town. Participants were each assigned a unique code and their data were stored with only this unique identifier. No names or other identifying information were stored with the experimental results. The recorded ADOS-2 interviews were only watched by ADOS-trained researchers to ensure accurate diagnostic scoring, and are stored on password-protected servers that are only accessible by the study investigators. No identifiable information or participant names will be used in publications.

Participants were reassured that their participation was voluntary and that they could discontinue the study at any time without any negative consequences. Participants were also allowed to take breaks between tasks if they felt tired or uncomfortable. All participants were compensated (R100 in total; approximately $9 at the time of the study) for their time at the end of the last session and were debriefed afterwards (see Appendix F). Participants were given general feedback about the nature and results of the study and the ADOS assessment,

and were given information about ASD if they requested it. Participants who suspected that they had a diagnosis of ASD were referred to the University of Cape Town's Student Wellness Centre or to a private clinical psychologist in Cape Town. Participants requesting further support for ASD were referred to psychologists, support groups and non-governmental organisations working with families with ASD.

Physiological Measurements

Electromyogram (EMG)

Surface EMG data was recorded with the BioSemi ActiveTwo system (www.biosemi.com, Amsterdam) with sintered 4 mm inner/ 11 mm outer diameter Ag-AgCl active electrodes (BioSemi TP FLAT) in a bipolar arrangement. Data were collected at a sampling frequency of 2048 Hz and a recording bandwidth of 417 Hz. Raw signals were digitised and filtered off-line with 30 Hz high-pass, 500 Hz low-pass and 50 Hz notch filters. Additionally, 125 ms moving average filters were applied to the data, as recommended in EMG guidelines (Fridlund & Cacioppo, 1986; Reicherts et al., 2012).

Autonomic Activity

The Vrije Universiteit Ambulatory Monitoring System (VU-AMS, Version 5fs; de Geus & van Doornen, 1996; Goedhart, Kupper, Willemsen, Boomsma, & de Geus, 2006; Willemsen, de Geus, Klaver, van Doornen, & Carrofl, 1996) was used for continuous recording of electrocardiogram (EKG), impedance cardiogram (ICG) and skin conductance (SCL) data. EKG was recorded using disposable, pregelled Ag-AgCl electrodes attached in a triangular, equidistant configuration on the precardium. Signals were sampled at 1000 Hz. ICG signals were measured by placing a four spot-electrode configuration whereby two electrodes supplying high-frequency current were placed on the back and two measuring electrodes were placed on the chest to detect the reduction in voltage over the thorax. The

two electrodes on the chest were placed at the suprasternal notch above the top of the sternum and at the processus xiphodius at the bottom of the sternum. The other two ICG electrodes were placed on the back, 3 cm higher than the suprasternal electrode and 3cm lower than the processus xiphodius electrode, respectively (see Figure 2). Respiration-related change in impedance (dZ) signals were sampled at 1000 Hz and raw impedance (Z_0) signals at 250 Hz. SCL was recorded using the constant voltage method (0.5 V), sampled at 10 Hz. An offline 60 Hz low-pass filter was applied to the ICG signal to minimise movement artefacts (Vrije Universiteit, 2015). Skin conductance was measured on the distal phalanx surfaces of participants' middle and index fingers of the left hand. Ag-AgCl, non-polarisable finger electrodes (6 mm diameter contact area; Biopac Systems, Inc.) and isotonic, 0.5% saline gel were used (GEL101, Biopac Systems, Inc.).

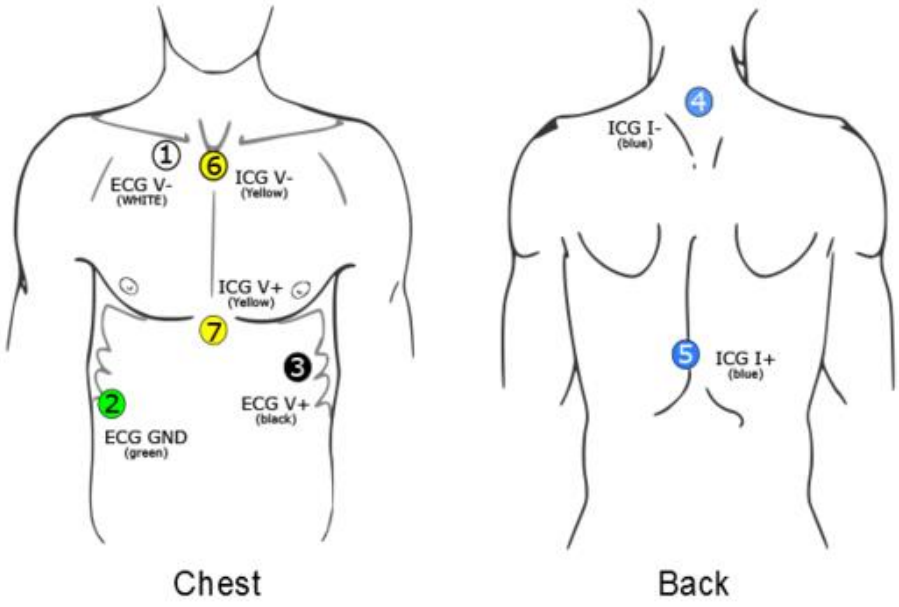

Figure 2. Electrocardiogram (EKG) and impedance cardiogram (ICG) electrode placement. From *Data Analysis and Management Software (DAMS) for the Vrije Universiteit Ambulatory Monitoring System (VU-AMS)*, version 1.2, 2015, p. 11. Copyright 2015 by the Vrije Universiteit.

VU-AMS data were analysed using the Vrije Universiteit Data Analysis and Management Software (VU-DAMS). The data were visually inspected for artefacts and these were manually corrected. The pre-ejection period was calculated (as detailed by Sherwood et al., 1990) as the time (in milliseconds) between the onset of the EKG Q-wave and the B-point in the ICG. ICG complexes were averaged over the entire period of interest using the Large Scale Ensemble Averaging method (Riese et al., 2003). Ensemble-averaged waveforms for each epoch of interest were visually inspected and the B-point and Q-wave onset were manually identified. Each participant was given an overall signal quality score (1−10; best = 10) for the non-discarded epochs and a confidence score in the B-point location (1–10; best =

10). The following anchor points were used when scoring signal quality: 10 = excellent signal quality, undisputable B-point location; 7 = some noise, but patterns are still clearly discernible; 3 = a great deal of noise/ inconsistency in the B-point location, or many discarded segments; 1 = signal is not discernible above the noise, many segments discarded. Signals with confidence scores less than 4 on either signal quality or B-point location were removed from the analyses, as recommended by the Vrije Universiteit (2015). Similarly, electrodermal (SCL) signal quality was rated from 1 to 10 (best = 10)[3] and signals with quality scores less than 4 were excluded from the analyses. Details of the amount of discarded data are given within each study.

Respiration rate was obtained from the filtered dZ signal. Respiration rate (in breaths per minute) was calculated from the time of the total respiratory cycle, starting from the beginning of an inhalation and terminating at the end of an exhalation. Tidal volume was calculated from the difference in amplitude between peaks and valleys in the dZ signal. RSA was calculated per experimental block. RSA scoring was done within the VU-DAMS software using the peak-valley method, which is highly robust against artefacts (de Geus, Willemsen, Klaver, & van Doornen, 1995; Goedhart, van der Sluis, Houtveen, Willemsen, & de Geus, 2007; Grossman, van Beek, & Wientjes, 1990). In other words, RSA was calculated by subtracting the shortest interbeat interval within an inspiration period from the longest interbeat interval within an expiration period. To control for the influence of respiration on RSA, RSA was predicted from participants' respiration rate and tidal volume per condition (as suggested in Grossman, Karemaker, & Wieling, 1991; Grossman & Taylor, 2007), and the residuals from analysis were used in subsequent analyses.

[3] Anchor points similar to that used for the ICG signal analysis were used when scoring SCL quality: 10 = excellent signal quality; 7 = some noise, but skin conductance reactions are still clearly discernible; 3 = a great deal of noise relative to skin conductance reactions; 1 = signal is not discernible above the noise.

Data Analysis

Mixed-Effects Modelling

Mixed-effects modelling is the main type of analysis used for the repeated measures data in this thesis. Mixed-effects modelling, also termed hierarchical linear modelling or multilevel modelling, is a statistical technique that is often used when multiple repeated measures are taken from the same participant or when participants are clustered into groups, such as schools. Psychophysiological studies are increasingly using mixed-effects modelling as it addresses the statistical challenges of having both within- and between-subject measurements (see Diamond et al., 2012; English, John, Srivastava, & Gross, 2012; Geisler et al., 2013; Marsh et al., 2008, for recent examples). Rather than averaging over trials or conditions, which reduces the amount of available information and may not accurately represent what is happening within a specific trial or condition, all trials or conditions are analysed. Linear mixed-effects modelling is similar to linear regression or mixed-repeated analysis of variance (ANOVA) in that it assumes that the outcome variable is continuous and that the residuals are normally distributed. Unlike mixed-repeated ANOVA, the independent variables do not need to be categorical, allowing greater statistical power. The use of continuous predictors rather than categorical ones, such as using amount of autism traits rather than diagnostic categories, is also consistent with the RDoC approach (Cuthbert, 2014). Unlike regression, the residuals do not need to be independent, as clusters of related data can be defined as part of the model (e.g. all data from the same participant). Furthermore, the residuals do not need to have constant variance, as nonconstant variance can be modelled as part of the analysis (Pinheiro & Bates, 2000; West, Welch, & Galecki, 2006).

Mixed-effects models contain two types of predictors: *Fixed effects* are parameters that contain all levels of a population variable, whereas *random effects* represent

experimental units sampled at random from a population - often participants in the case of repeated measures data (Pinheiro & Bates, 2000). Regression models contain only fixed effects; in other words, the predictors have unchanging (fixed) intercepts. In mixed-effects modelling, instead of estimating one fixed slope and intercept for the regression line (which applies to all participants) of a predictor, slopes and intercepts are allowed to vary across participants and across conditions within a participant. Intercepts that are not fixed are referred to as random intercepts and slopes that are allowed to vary are referred to as random slopes. A model may have one or many random intercepts, and additionally, may or may not contain multiple slopes. Simply put, fixed effects provide estimates of group averages (e.g., means and regression coefficients), whereas random effects provide estimates of group variance (Merlo, Yang, Chaix, Lynch, & Råstam, 2005). The estimated (unstandardized) average of the correlation coefficients of the fixed effects in a mixed-effects model is indicated by the symbol **β**.

In the analyses presented in this thesis, all variables of interest were added as fixed effects in the models. Additionally, most of the mixed-effects models presented in this thesis have participant ID as a random intercept (in other words, a different intercept for the regression line is estimated for each participant) and have a maximal random-effect structure as is recommended for experimental and quasi-experimental designs (Barr, Levy, Scheepers, & Tily, 2013). In other words, slopes were allowed to vary for all experimentally controlled manipulations, much as experimental conditions are used as independent variables in a mixed-repeated ANOVA. For example, in Study 2, the experimentally-controlled factors were *condition* and *muscle*. Hence, condition, muscle and their interaction were entered into the model as random slopes. Thus each condition-muscle combination within a participant was allowed an independently varying slope. If a model did not converge, a simpler random-effect structure was specified. After the random-effect structure was chosen, fixed effects

were removed in a top-down fashion to select the optimal model (Zuur, Ieno, Walker, Saveliev, & Smith, 2009). In order for the correlation coefficients to be comparable and to reduce collinearity between fixed effects, continuous fixed effects were scaled so that they had a mean of zero and standard deviation of one.

The advantages of using mixed-effects modelling are that (1) it is more accurate in identifying relationships when observations are not independent, such as when data are collected from the same participant at multiple time points, and that (2) it is more robust to missing data. Unlike ANOVA, which utilises listwise deletion of missing data, mixed-effects models use all available observations for a given participant (West et al., 2006). (3) Mixed-effects modelling is also robust to violations of homoscedasticity, as a specific variance pattern (e.g. exponentially increasing variance) can be modelled as part of the analysis. This makes mixed-effects modelling a far more flexible and powerful means of analysis for repeated measures data than either multiple regression or mixed-repeated ANOVA. However, because of the random components in the model, significant values and effect sizes are guidelines rather than exact values. The reporting of significance and coefficients of determination (effect sizes) are controversial (Bates, 2006). However, for ease of comparison with the more familiar regression model, I have reported both in this thesis. Two coefficients of determination are reported: The *marginal coefficient* (R^2_M) is an index of the amount of variance explained by the fixed factors; whereas the *conditional coefficient* (R^2_{cond}), is an index of the amount of variance that is explained by the cumulative effects of the fixed and the random factors (Johnson, 2014; Nakagawa & Schielzeth, 2013). Some authors report the degree of similarity between cases within a cluster or unit of analysis (given by the intraclass correlation coefficient). However, the intraclass correlation coefficient cannot be meaningfully calculated for models with both random intercepts and random slopes, as the amount of similarity differs for each value of the predictor (Goldstein, Browne, & Rasbash,

2002). Rather than reporting intraclass correlation coefficients for models, I have reported the model variance components throughout.

Though mixed-effects models are fairly flexible in their application, they do make some assumptions regarding the data. First, residuals should be independent within a cluster or level (e.g. within a participant, in the case of repeated measures). If residuals covary, temporal or spatial correlations between residuals should be explicitly modelled. Second, the residuals should be normally distributed, with a mean of zero, within a cluster. Third, error variance should be homogenous or should be explicitly modelled within the analysis. Fourth, linear mixed-effects models assume a linear relationship between each of the predictors and the outcome variable. Fifth, predictor variables should not have high correlations with each other (multicollinearity). Lastly, predictor variables should not contain an overabundance of zeroes (zero-inflation), as this can affect model accuracy. To determine whether assumptions were satisfied for each model, each model was inspected by creating scatterplots of the relationship between the predictor and outcome variables. Furthermore, residual plots were inspected for independence of errors, normality, homogeneity of variance and the absence of outlying values. Residuals were also plotted against fitted values to test for nonlinearity. Collinearity was examined by calculating the variance inflation factor, a measure of the extent to which variance in the estimated regression coefficients is inflated due to the presence of correlated variables. Coefficient confidence intervals were also examined for unwanted patterns. Histograms of the variables were inspected for normality and zero-inflation. More information about these procedures can be found elsewhere (Zuur, Ieno, & Elphick, 2010; Zuur et al., 2009). Unless specifically reported, assumptions were upheld for each model. Heterogeneity of variance was addressed by first modelling the variance patterns within the mixed-effects or generalised least squared model, and if this was not successful, transforming the outcome variable. To address multicollinearity, variables with high variance

inflation factors (> 3) were systematically removed from the models to improve fit. Where scatterplots indicated possible nonlinear correlations, higher-order terms (e.g. quadratic or cubic terms) were included in the models. Influential values were removed and reported. There were no cases of temporal correlation between residuals or zero-inflation in any of the models.

Data analysis was done in `R` version 3.2.5 (R Core Team, 2015) and RStudio (RStudio Team, 2015). Most random and mixed-effects models reported within this thesis were computed with bound optimisation by quadratic approximation (BOBYQA; Powell, 2009) and restricted maximum likelihood (REML) estimation using the `lmerTest` package (Kuznetsova, Brockhoff, & Christensen, 2015). The exception is where heterogeneous variance was modelled as part of the analysis. These models were run using the `nlme` package (Pinheiro, Bates, DebRoy, Sarkar, & R Core Team, 2016), as `lmerTest` does not allow variance structures. Cells with missing data were omitted from the analysis. Throughout the studies, type III ANOVA results with Satterthwaite correction for degrees of freedom are reported. Conditional and marginal coefficients of determination (effect sizes) for the mixed-effects models were estimated using the `r.squaredGLMM` function in the `MuMIn` package (Bartoń, 2016; Nakagawa & Schielzeth, 2013). Where appropriate, significant differences in categorical fixed effects were examined post hoc using the `multcomp` package (Hothorn, Bretz, & Westfall, 2008), or by doing one-way paired *t*-tests of the specific groups of interest, as suggested in Howell (2004). Data visualisation was done using the `ggplot2` (Wickham, 2009) and `sjPlot` (Lüdecke, 2016) packages. Appendix G contains the full list of `R` packages used during data analysis.

CHAPTER 5.

STUDY 1: THE EMPATHY PROFILE IN ASD

This study examined whether trait levels of cognitive empathy and self-regulation are negatively correlated with autism traits, while affective empathy is not correlated with autism. Trait levels of the different facets of empathy, alexithymia and autism were measured via self-report. Furthermore, cognitive empathy was measured with two cognitive tasks, a dynamic emotion recognition task and a faux pas recognition task. The correlation between empathy and autism traits was examined in two samples: An online sample representing the typical distribution of autism traits in the population, and a laboratory sample of roughly equal numbers of low, medium and high autism trait individuals case-matched on age, sex, and race (participant details are described in Chapter 4). A secondary aim of this study was to create affective empathy, cognitive empathy and self-regulation composite scores for each individual to use as predictors in Studies 2 and 3.

Research Questions and Hypotheses

To what extent are the different facets of empathy (affective, cognitive, self-regulation) associated with ASD?

Hypothesis I: Amount of autism traits, measured by Autism Index (AI) scores, will be negatively correlated with trait cognitive empathy and with self-regulation, even after alexithymia is controlled for. AI scores will not be correlated with trait affective empathy.

Hypothesis II: Amount of autism traits, measured by AI scores, will be negatively correlated with performance cognitive empathy.

Methods

Design

The study used a correlation design. Amount of autism traits was correlated with trait affective empathy, trait cognitive empathy, trait self-regulation and alexithymia in both the online (N = 519) and laboratory samples (N = 98) described in Chapter 4. Additionally, performance measures of cognitive empathy were taken in the laboratory sample, and correlated with amount of autism traits.

Materials and Methods

Observational measures. The Autism Diagnostic Observation Schedule, second edition (ADOS-2; Lord et al., 2012), is a semi-structured observational interview designed to elicit behaviours related to autism. The ADOS-2 adolescent and adult module (Module 4) was used for all participants. This module features scores for communication, reciprocal social interaction, and stereotyped behaviour and repetitive interests. A diagnostic algorithm score is calculated from the diagnostic items on the communication and reciprocal social interaction sections. The ADOS-2 has good predictive validity against best estimate diagnoses (Gotham, Pickles, & Lord, 2008; Lord et al., 2000). The ADOS-2 was administered by research-trained ADOS administrators. All observations were recorded for coding purposes. Difficult cases were coded by a team of three research-reliable coders and consensus coding was used for these cases (10% of participants).

Self-report measures. The Autism-Spectrum Quotient (AQ; Baron-Cohen, Wheelwright, Skinner, Martin, & Clubley, 2001) is a 50-item self-report questionnaire on social and communicative skills, imagination, attention to details, and attention switching. Questions are rated on a 4-point Likert scale ranging from *definitely agree* to *definitely disagree*. The Autism-Spectrum Quotient was designed as a screening tool for adults with

ASD and has good internal consistency (.63 - .77) and test-retest reliability (.70). Higher scores indicate greater amounts of autistic traits, and scores above 26 are indicative of potential ASD (Woodbury-Smith et al., 2005). To increase the range of scores, the scoring for the AQ was changed so that *definitely disagree* = -2, *slightly disagree* = -1, *slightly agree* = 1 and *definitely agree* = 2. The original scoring was *definitely disagree* and *slightly disagree* = 0, and *slightly agree* and *definitely agree* = 1. The questionnaire items are given in Appendix H.

Trait empathy was measured using the Interpersonal Reactivity Index (IRI; Appendix I) and Emotional Contagion Scale (ECS; Appendix J). The Interpersonal Reactivity Index (Davis, 1980) is a widely used self-report measure of dispositional empathy. It is composed of four subscales: perspective taking, fantasy, empathic concern, and personal distress. Items are scored on a 5-point Likert scale from *does not describe me well* to *describes me very well*. All subtests have acceptable internal consistency (.70 - .78) and test-retest reliability (.62 - .81), with fantasy having the highest test-retest reliability and perspective taking the lowest. The Emotional Contagion Scale (Doherty, 1997) consists of 15 questions and measures susceptibility to 'catching' others' emotions. The Emotional Contagion Scale focuses on five emotions; happiness, sadness, anger, fear, and love. Each emotion is measured by three items that are scored on a 5-point Likert scale from *not at all* to *always*. The Emotional Contagion Scale has excellent internal consistency (.90) and test-retest reliability (.84). Both measures have been used successfully with participants with ASD (Lombardo et al., 2007; Mathersul et al., 2013; Silani et al., 2008). On both measures, high scores indicate greater empathy.

To reduce the number of subscales and to correspond to Decety's (2011) definition of empathy, the items from the ECS and IRI were combined to form affective empathy, cognitive empathy and self-regulation scales. Items were assigned to the different facets based on theory by two raters familiar with the empathy literature. Where there were

disagreements, a consensus was reached over which facet an item falls under. Internal consistency was calculated for each of the subscales (see Results, p. 74 and p. 81, and Appendix K). Appendix K shows the results of a confirmatory factor analysis of the empathy facets and gives a list of the items on each scale. Example items for the different facets are "I often have tender, concerned feelings for people less fortunate than me" (affective empathy), "I sometimes try to understand my friends better by imagining how things look from their perspective" (cognitive empathy), and "When I see someone who badly needs help in an emergency, I go to pieces" (self-regulation; negatively keyed). IRI item 1 ("I daydream and fantasize, with some regularity, about things that might happen to me") did not fit well with any of the empathy scales, and was excluded. The scores on the affective, cognitive, and self-regulation scales were used as predictors for the analyses in this study, as well as Studies 2 and 3.

Alexithymia was measured using the 20-item Toronto Alexithymia Scale (TAS-20; Bagby, Parker, & Taylor, 1994; Bagby, Taylor, et al., 1994). The scale measures difficulties in identifying and describing emotions, and the tendency to focus on external information rather than emotional experience. It consists of 20 items that are rated using a 5-point Likert scale (where 1 = *strongly disagree* and 5 = *strongly agree;* i.e., higher scores indicate greater alexithymia). Overall, the 20-item Toronto Alexithymia Scale has acceptable test-retest reliability (.77), good internal consistency (.81) and has been used with ASD populations (e.g., Lombardo et al., 2007; Silani et al., 2008), where it has shown good test-retest reliability (Berthoz & Hill, 2005). The internal consistencies of the subscales range from .66 (Externally Oriented Thinking) to .78 (Difficulty Identifying Feelings; Bagby, Parker, et al., 1994). The questionnaire items are given in Appendix L.

Performance cognitive empathy. Accuracy and speed in recognising basic emotions was measured using emotional expressions from *The Montreal Set of Facial Displays of Emotion* (Beaupré & Hess, 2005). Video morphs were created from the static images using FantaMorph 4 (Abrosoft, Lincoln, NE). Black and white morphed videos, all 14s in length, showed faces slowly transitioning from a neutral expression to one of six emotions (anger, fear, sadness, disgust, happiness or shame). Equal numbers of Black and White male and female faces were presented for each of the emotions. Example stimuli are shown in Figure 3. Participants pressed a button as soon as they recognised the emotion, and then chose the correct emotion from a list. The software captured participants' responses and the time taken to respond. Response latency was measured in two ways: Time spent looking at the face before keypress (Response Time 1), and time spent selecting an emotion (Response Time 2).

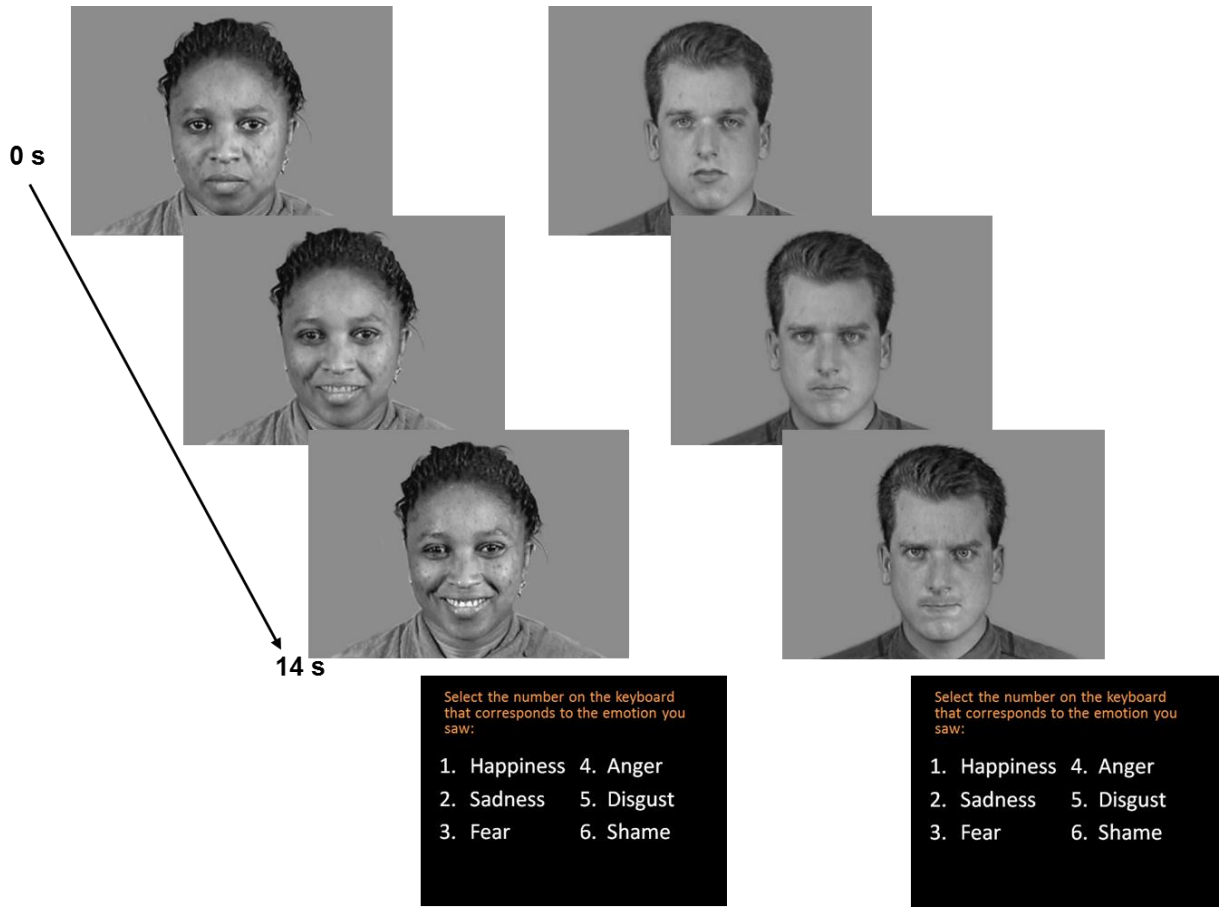

Figure 3. Example stimuli from the emotion recognition task. Three clips from one of the videos representing happiness are shown on the left, and three clips from one of the videos representing anger are shown on the right. From http://www.psychophysiolab.com/en/download.php.

The *Faux Pas* task (Stone, Baron-Cohen, & Knight, 1998) was administered as a measure of higher-order cognitive empathy. This task contains 10 stories wherein a character says something that is awkward or embarrassing, and 10 control stories wherein no embarrassing events take place. After reading the story, participants were asked whether anyone said anything awkward or anything they should not have said. If the participant indicated that something awkward was said, the researcher asked "Who said something they

shouldn't have said or something awkward?", "Why shouldn't he/she have said it or why was it awkward?", and "Why do you think he/she said it?". Each story also contained an emotion understanding question, "How do you think X felt [upon hearing the faux pas]?" and two to three control questions that assessed the participant's comprehension of the story. Three scores were derived for this task: A Faux Pas Total Score, out of 120, which consisted of all the faux pas inference questions; a Faux Pas Emotion Recognition Score, out of 10, which contained only the results of the emotion understanding questions; and a Faux Pas Control Score, out of 41, which consisted of only the control question totals.

Use of questionnaire and cognitive measures in a South African sample. The Interpersonal Reactivity Index has shown good internal consistency in South African samples (e.g., MacRitchie, 2006; Robins, Meltzer, & Zelikovsky, 2009). The 20-item version of the Toronto Alexithymia Scale (Erhabor & Ndlovu, 2013) has also been used in South Africa, though the authors unfortunately do not report any reliability indices. As far as I am aware, the Emotional Contagion Scale and the Autism-Spectrum Quotient have not been used in a South African sample before. To investigate possible problems with the reliability of the scales in this sample, the internal consistency of all the questionnaires were assessed before starting inferential statistics.

Regarding the performance measures, both the child and the adult versions of the faux pas test have been used in South African samples (Hoogenhout & Malcolm-Smith, 2014; Lindinger et al., 2016; Mc Grath, 2009). Underperformance on the faux pas test within certain South African population groups has been reported (Lazarus, 2009), but as participants with low, medium and high autism traits were matched on age, sex and race, such an effect should not bias the relationship between autism traits and cognitive empathy. The specific dynamic facial displays have to my knowledge not been used in a South African sample, but South African adults were found to perform well on related static facial

expression images (Leppänen et al., 2006, 2008). To my knowledge, there is no published work on the use of the adolescent and adult module (module 4) of the ADOS-2 in South Africa. However, the ADOS-2 has been used successfully in several different countries, including Romania, Korea, Norway and the Netherlands (Bildt, Sytema, Meffert, & Bastiaansen, 2015; Lord et al., 2012; Pantelis & Kennedy, 2016). A pre-pilot of the Afrikaans translation of ADOS-2 revealed that participants deemed the social interaction tasks appropriate for use in South Africa (L. Smith, Malcolm-Smith, & de Vries, 2016).

Procedure

All participants gave informed consent and completed the self-report measures online on the survey website Survey Monkey (http://www.surveymonkey.com; see Appendix M for full survey). Survey Monkey access is password-controlled to ensure participant anonymity and adheres to the US-EU and US-Swiss Safe Harbour Frameworks regarding the collection, use and storage of personal information. Participant responses were sent over secured, encrypted Secure Sockets Layer and Transport Layer Security (SSL/TLS) connections. Participants had the option of completing the survey in the laboratory, with assistance from the experimenter as needed (e.g., definitions of some words).

The smaller laboratory sample was selected based on their scores on the online AQ, as described in Chapter 4, and were invited to participate in the lab-based part of the study. Participants in the laboratory sample were given further verbal information about the study and confirmed consent at the start of the two laboratory sessions. The ADOS-2 assessment was completed during the first session, and the emotion recognition and faux pas tasks on separate days. The laboratory sessions lasted approximately 30 – 40 minutes each. Emotion recognition stimuli were presented within E-Prime 2 (Psychology Software Tools, Pittsburgh, PA) on a 19-inch 4:3 aspect ratio monitor. Instructions were presented verbally and on the

screen, and participants were given a practise trial before starting the experiment. Participants were instructed to identify the displayed emotions as quickly and accurately as they could. They were asked to press Enter as soon as they recognised the emotion, and advised that once they pressed Enter they would no longer be able to view the expression. Each emotion was displayed three times (18 trials in total) in random order. The faux pas stories were presented in book format. Instructions were read to the participants. Printed stories were kept in front of the participants as a memory aid and participants were told that they could consult the story at any time during the questions. Stories were always presented in the same order.

Data Analysis

Total scores on the ADOS-2 diagnostic algorithm (i.e., the social and communication algorithm totals) and AQ were centred and scaled and then aggregated to calculate an Autism Index (AI) score. Autism Index scores are indicative of amount of autism traits, with positive scores indicating higher than average autism traits. Autism Index scores were used as a continuous variable in most analyses. To make the comparison of demographic information easier, autism index scores were also split into tertiles to form low, medium, and high autism traits groups. The groups' demographic profiles were compared with ANOVA or chi-squared tests, according to the nature of the data.

To correspond to Decety's (2011) definition of empathy, items from the ECS and IRI were combined to form affective empathy, cognitive empathy, and self-regulation scales. The reliability of the original scales and new subscales were assessed using the packages `psych` (Revelle, 2015) and `lavaan` (Rosseel, 2012). Reliability analyses were done for the total sample and again separately for participants who also completed the lab-based component of the study. In both samples, linear regressions were used to correlate the new affective

empathy, cognitive empathy, and self-regulation indices with AI scores and with each other. Alexithymia was used as a control variable in analyses with AI.

I used linear random-effects models to predict emotion recognition accuracy and response times. Medication use, AI, alexithymia, and type of emotion were used as fixed effects. Participant ID was used as the random intercept, and emotion type was used as the random slope (response time models only). Next, Faux Pas total and emotion recognition scores were predicted from control question accuracy, medication use, alexithymia, and AI. Generalised least squares models with an exponential variance structure were used for these models, as both the total and the emotion recognition scores showed increasing variance with increasing AI scores (as recommended in Zuur et al., 2009). The packages `lmerTest` (Kuznetsova et al., 2015) and `nlme` (Pinheiro et al., 2016) were used to calculate the random-effects models and general least squares models, respectively. Finally, a performance cognitive empathy aggregate was calculated from the two tasks that were predicted to be most sensitive to subtle cognitive empathy deficits: emotion recognition response time and the total faux pas score.

Results

Total Sample

The total sample who completed the online questionnaires was of mean age 22.73 years, *SD* = 5.71 (253 males, 266 females; 230 White, 157 Black, 74 Mixed Race, 41 Indian, 5 Other).

Scale reliability. The reliability of the scales and subscales was assessed using Cronbach's alpha. Overall, both the original and new scoring versions of the AQ had high internal consistency (α_{new} = .86, $\alpha_{original}$ = .83, *N* = 518). The AQ subscales also had satisfactory internal consistencies with the new scoring (see Table 1). One item, AQ item 30 ("I don't usually notice small changes in a situation, or a person's appearance") was negatively correlated with the rest of the items (r_{cor} = -. 16) in both AQ versions, though it is meant to be positively correlated with ASD.

As shown in Table 1, the empathy and alexithymia questionnaires had high internal consistency in this sample: All questionnaires had Cronbach's α values of .85 – .86 (95% confidence intervals all between .83– .88). The internal consistencies of the questionnaire subscales were also good, except for the External Thoughts subscale of the TAS-20, which had low internal consistency (see Table 1). Two of the items in this subscale were problematic: Item 5 on the TAS-20 had a negative correlation with the rest of the items (r_{cor} = - .17), and item 16 had a correlation < .20 with the other items. To reduce the number of subscales and to correspond to Decety's (2011) definition of empathy, the items from the ECS and IRI were combined to form affective empathy, cognitive empathy and self-regulation scales. IRI item 1 ("I daydream and fantasize, with some regularity, about things that might happen to me") did not fit well with any of the empathy scales, and was excluded. The new scales had high internal consistency. The specific items in each of the new scales are discussed more fully in the Laboratory Sample section.

Table 1

Internal Consistency of the Autism, Empathy and Alexithymia Subscales

Questionnaire	Cronbach's α	95% Confidence Interval	*N*
AQ (new)	.86	.85 - .88	518
Social skill	.81	.78 - .83	
Attention switching	.65	.60 - .69	
Attention to detail	.69	.65 - .73	
Communication	.74	.70 - .77	
Imagination	.64	.59 - .68	
ECS	.86	.84 - .88	519
IRI	.85	.83 - .87	518
Empathic concern	.83	.81 - .85	
Personal distress	.72	.68 - .76	
Perspective taking	.75	.71 - .78	
Fantasy	.81	.79 - .84	
TAS-20	.85	.83 - .86	518
Identify emotions	.88	.86 - .89	
Describe emotions	.81	.79 - .84	
External thoughts	.54	.48 - .60	
New scales			
Affective empathy	.90	.89 – .921	518
Cognitive empathy	.76	.73 – .79	518
Self-regulation	.73	.69 – .76	518

Note. ECS = Emotional Contagion Scale; IRI = Interpersonal Reactivity Index; TAS-20 = 20-Item Toronto Alexithymia Scale.

Autism and trait empathy and alexithymia. The sample had autism, empathy and alexithymia scores within previously reported average ranges (Bagby, Taylor, et al., 1994; Baron-Cohen et al., 2001; Davis, 1980; Doherty, 1997; Franz et al., 2007). AQ scores, using the original scoring criteria, ranged from 0 (no/minimal autism traits) to 48 (very high likelihood of ASD; max = 50). Descriptive statistics for the sample are presented in Table 2. AQ scores were negatively correlated with cognitive empathy (r [512] = - .35, $p < .001$), affective empathy (r [512] = - .32, $p < .001$), and self-regulation (r [512] = - .19, $p < .001$). In contrast, AQ scores were positively correlated with alexithymia (r [513] = .56, $p < .001$). Figure 4 shows the uncorrected correlations.

After controlling for alexithymia, AQ scores still significantly predicted trait affective empathy, β = - 0.15, SE = 0.03, ΔR^2 = .03, t = - 4.69, $p < .001$, and trait cognitive empathy, β = -0.06, SE = 0.01, ΔR^2 = .05, t = -5.62, $p < .001$, but not self-regulation, β = - 0.02, SE = 0.01, ΔR^2 = .003, t = - 1.53, $p \leq .127$ in a linear regression model.

Table 2

Empathy, Autism and Alexithymia Traits in the Full Sample

Questionnaire	*M*	*SD*	Questionnaire	*M*	*SD*
Empathy scales			**Autism traits**		
ECS (max = 60)	36.43	9.71	AQ rescaled (max = 100)	- 16.95	24.56
IRI (max = 112)	67.51	14.37	AQ original (max = 50)	19.78	7.66
Empathic concern	19.82	5.41			
Personal distress	12.33	4.96			
Perspective taking	17.08	4.94	**Alexithymia**		
Fantasy	18.29	5.95	TAS-20 (max = 100)	50.65	12.2
Affective empathy (max = 96)	61.5	15.08	*Identify emotions*	16.89	6.69
Cognitive empathy (max = 28)	17.38	4.96	*Describe emotions*	15.01	4.82
Self-regulation (max = 32)	17.77	5.55	*External thoughts*	18.76	4.36

Note. ECS = Emotional Contagion Scale; IRI = Interpersonal Reactivity Index; TAS-20 = 20-Item Toronto Alexithymia Scale.

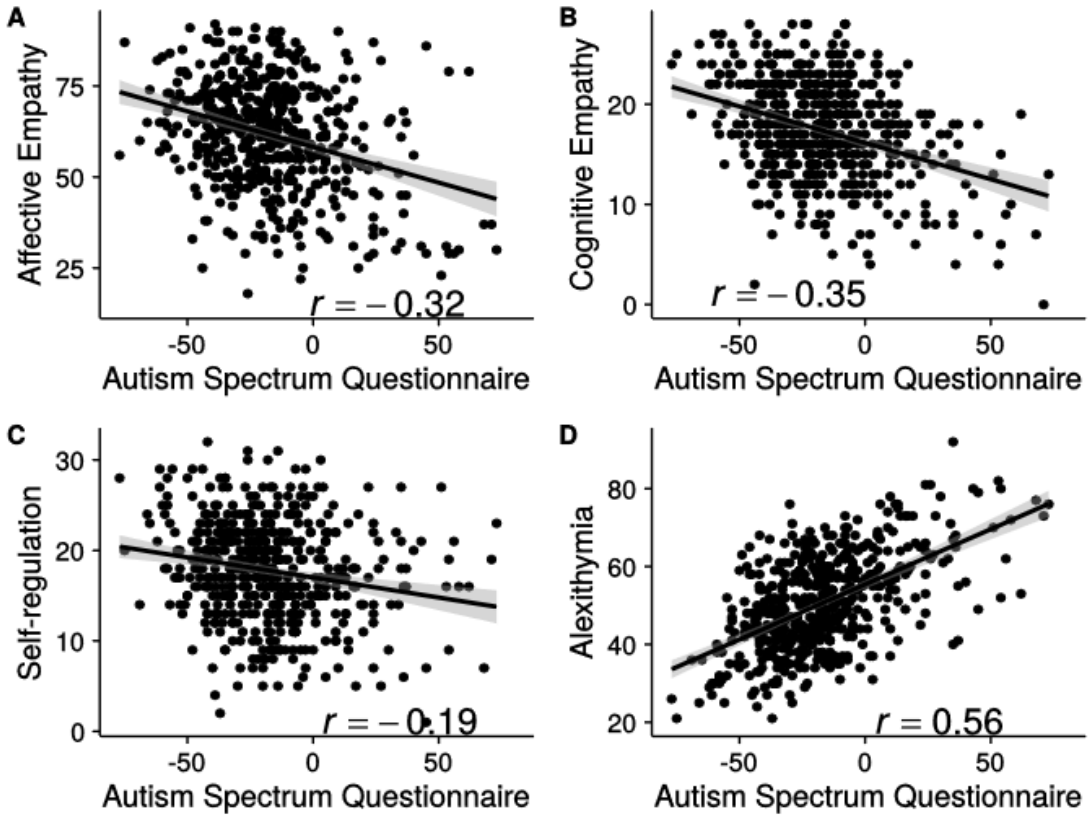

Figure 4. The relationship between autism traits, empathy and alexithymia in the total sample. Shaded areas indicate the 95% confidence intervals around the prediction. Correlation coefficients are not corrected for alexithymia.

Males had significantly higher AQ scores than females (M_M = -13.78, SD_M = 25.12, M_F = - 19.93, SD_F = 23.59, t [720] = - 3.52, $p \leq .0005$, d = 0.25). In contrast, females had significantly higher affective (M_M = 56.00, SD_M = 16.74, M_F = 66.70, SD_F = 17.99, t [500] = 8.58, $p < .001$, d = 0.76) and cognitive empathy scores (M_M = 16.74, SD_M = 4.90, M_F = 17.99, SD_F = 4.96, t [514] = 2.90, $p \leq .004$, d = 0.25), but lower self-regulation scores (M_M = 19.14, SD_M = 5.39, M_F = 16.48, SD_F = 5.41, t [514] = - 5.58, $p < .001$, d = 0.49). In other words, females had better affective and cognitive empathy, but poorer regulation of emotion during distress. Males had significantly higher alexithymia scores than females (M_M = 52.10, SD_M = 12.02, M_F = 49.27, SD_F = 12.24, t [515] = -2.66, $p \leq .008$, d = 0.23). Affective empathy was significantly positively correlated with cognitive empathy, r (517) = .51, $p < .001$, and

negatively correlated with self-regulation scores (r [517] = - .43, $p < .001$). Cognitive empathy and self-regulation were not correlated (r [517] = - .08, $p \leq .057$).

Laboratory Sample

Demographic information. The low, medium and high ASD groups did not differ in age, F (2, 95) = 0.29, $p \leq .750$, $\eta^2 = .006$; race, χ^2 (6, N = 98) = 10.86, $p \leq .092$, Cramer's V = .24; or sex, χ^2 (2, N = 98) = 2.31, $p \leq .314$, Cramer's V = .15[4]. Medication use was significantly higher in the high autism traits group than the low and medium groups, χ^2 (2, N = 98) = 25.77, $p < .001$, Cramer's V = .52 (std. residuals: Low = - 2.26, Medium = -2.77, High= 5.07).[5] The medications included antidepressants (citalopram, escitalopram, amitriptyline, fluoxetine; 7% of participants), stimulants (methylphenidate; 4% of participants), antipsychotics (risperidone, ziprasidone; 4% of participants), anticonvulsants (sodium valproate, lamotrigine, phenytoin; 3% of participants) and others (allergy and asthma medication, oral contraceptives, cholesterol medication; 9% of participants). Of the 98 participants, 6% were on more than one type of medication. For a full list of medications, see Appendix O.

As the groups did not differ in age, sex or race, these variables were not included in subsequent analyses. Medication use was included in all analyses as it could potentially affect physiological and behavioural outcomes. Group demographics are shown in Table 3.

[4] The results of the Chi-squared test should be interpreted with caution, as more than 20% of the cells had low expected frequencies. However, a linear regression predicting AI score from Race also had a non-significant result; $R^2_{adj} = 0$, F (3,94) = 0.68, $p \leq .569$.

[5] Similarly, a logistic regression predicting medication use from AI showed that with every one-unit increase in AI, participants were 1.77 times more likely to be on medication, 95% CI [1.31, 2.39], z (97) = 3.69, p $\leq$ .0002.

Table 3

Participant Demographics

	Autism traits		
	Low	Medium	High
N	33	33	32
Sex: Male	24	27	28
Age	25.52 (7.65)	24.18 (9.80)	25.69 (8.75)
Race			
White: Black: Mixed: Indian	25:4:3:1	14:8:7:4	23:2:4:3
Medication: Yes*	3	2	17[a]
ADOS-2 communication	0.03 (0.17)[a]	0.52 (0.71)[b]	3.03 (2.19)[ab]
ADOS-2 social interaction	0.21 (0.42)[a]	0.85 (0.91)[b]	6.16 (3.11)[ab]
ADOS-2 diagnostic*	0.24 (0.44)[a]	1.36 (1.37)[b]	9.19 (4.94)[ab]
ADOS-2 total*	1.79 (2.12)[a]	5.48(4.36)[b]	21.50 (12.88)[ab]
AQ original*	12.79 (3.73)[a]	22.70 (6.09)[a]	32.50 (7.55)[a]
AQ rescaled*	- 38.97 (14.9)[a]	- 6.76 (18.37)[a]	26.09 (27.30)[a]
AI*	- 1.63 (0.41)[a]	- 0.44 (0.56)[a]	2.13 (1.09)[a]

Note. For continuous variables, means are given with standard deviations in parentheses. Asterisks (*) indicate significant between-group differences. ADOS-2 diagnostic = ADOS-2 diagnostic algorithm score, consisting of the communication and social interaction algorithm totals; ADOS-2 total = ADOS-2 total score (all items); AQ = Autism Spectrum Quotient; AI = Autism Index.

[a,b] Between-group differences on Tukey's post hoc testing. Groups with the same superscript are significantly different from each other.

Scale reliability. Similar to the results from the total sample, both the original and new scoring versions of the AQ showed high reliability (α_{new} = .92, $\alpha_{original}$ = .90); as did the AQ subscales (αs = .74 - .86). The ADOS-2 diagnostic algorithm (α = .92), IRI (α = .83) and ECS (α = .88) also showed high reliability. AQ item 30 was again negatively correlated with autism traits (r_{raw} = - .13, r_{cor} = -. 16) in both AQ versions. The TAS-20's reliability was satisfactory overall (α = .84), but poor for the Externally-Oriented Thinking subscale (α = .49). To keep the scales consistent with the original versions, problem items were not removed from the scale total calculations.

Reliability analysis of the new affective empathy, cognitive empathy and self-regulation scales revealed that three items had correlations < .35 with their respective subscales (affective empathy: IRI 12, ECS13; self-regulations: ECS7; cognitive empathy: IRI15). These items were removed from the scales and the reliability was reassessed (see Table 4 for item descriptions). The final affective empathy scale had a reliability of .91, 95% CI [.87, .94], the cognitive empathy scale had a reliability of .72, 95% CI [.59, .84], and the self-regulation scale had a reliability of .80, 95% CI [.71, .90]. For a list of the items comprising each subscale and their α-values, see Appendix K.

Table 4

Excluded Items from the Interpersonal Reactivity Index (IRI) and Emotional Contagion Scale (ECS)

Item	Description	Correlation
IRI 1	daydreams and fantasizes regularly	
Affective empathy		
IRI 12[a]	rarely becomes extremely involved in book/movie	.20
ECS13	gets tense around people who are stressed	.24
Cognitive empathy		
IRI15[a]	if right, doesn't waste time listening to others' argument	.32
Self-regulation		
ECS7[a]	gets irritated around angry people	.24

Note. Correlations are corrected for item overlap and scale reliability (Cureton, 1966; Revelle, 2015).

[a] Negatively keyed items.

Some individual items had moderately low correlations with other scale items ($.35 \leq r \leq .40$). These items were kept in the scales, but are noted here. IRI 7 ("I am usually objective when I watch a movie or play, and I don't often get completely caught up in it"), IRI 18 ("When I see someone being treated unfairly, I sometimes don't feel very much pity for them") and ECS 10 ("I tense when overhearing an angry quarrel") had low correlations with the affective scale total. Similarly, IRI 3 ("I sometimes find it difficult to see things

from the "other guy's" point of view") and 8 ("I try to look at everybody's side of a disagreement before I make a decision") had low correlations with the cognitive empathy total, and IRI 10 ("I sometimes feel helpless when I am in the middle of a very emotional situation") had a low correlation with the self-regulation total.

Autism and trait empathy and alexithymia. The mean ADOS-2 diagnostic algorithm total for the sample was 3.54 (*SD* = 4.93; see Table 3 for group totals). Scores higher than 2 on Communication, 4 on Social Interaction, *and* 7 on the diagnostic Communication-Social Interaction Total are necessary to meet the cut-off for ASD on the ADOS-2. Likewise, scores higher than 3 on Communication, 6 on Social Interaction, *and* 10 on the diagnostic Communication-Social Interaction Total are necessary to meet the cut-off for autism on the ADOS-2. In total, 21 participants in the high AI group met the criteria for ASD, of which 14 also met the criteria for autism. Similarly, 24 participants had scores of 32 or higher on the original AQ algorithm, indicating a high likelihood of ASD (Baron-Cohen et al., 2001). The mean AQ score for the sample was -6.88 (*SD* = 33.54) on the rescaled algorithm and 22.53 (*SD* = 9.82) on the original algorithm. ADOS-2 algorithm and AQ rescaled algorithm scores were significantly positively correlated, r (96) = .50, $p < .001$.

The descriptive statistics for the empathy and alexithymia subscales are given in Table 5. Participants in the low AI group performed in the average range on affective empathy, cognitive empathy, self-regulation and alexithymia. On average, the high AI group (*M* = 62.13, *SD* = 11.31) fell within the clinical range for alexithymia, which is defined as scoring 61 or higher on the TAS-20 (Bagby, Taylor, et al., 1994). Fifteen of the high AI group participants (48%) met criteria for alexithymia, whereas only 27% of the medium AI and 12% of the low AI group participants met the clinical cut-off.

Table 5

Empathy and Alexithymia Scores

	Autism traits							
	Low		Medium		High		Total	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Empathy scales								
ECS (max = 60)	35.00	8.10	31.12	10.87	30.75	12.42	32.31	10.66
IRI (max = 112)	64.76	13.04	62.27	12.78	58.03	16.31	61.80	14.18
Empathic concern	19.42	4.62	17.24	5.73	17.17	5.74	17.97	5.43
Personal distress	10.21	5.29	11.48	4.78	14.37	5.17	11.95	5.31
Perspective taking	18.82	4.48	16.45	4.24	12.20	4.23	15.94	5.07
Fantasy	16.30	5.51	17.09	5.16	14.30	6.48	15.95	5.77
Trait affective empathy (max = 96)	58.39	13.72	53.82	14.58	51.30	18.63	54.60	15.80
Trait cognitive empathy (max = 28)	18.67	4.31	16.55	4.57	12.80	4.74	16.10	5.09
Self-regulation (max = 32)	11.79	6.08	13.06	5.63	16.20	6.04	13.60	6.13
Alexithymia scales								
TAS-20 (max = 100)	47.00	11.22	54.88	10.09	62.13	11.31	54.52	12.41
Identify emotions	14.79	5.82	18.18	6.41	23.58	6.50	18.75	7.16
Describe emotions	13.82	4.77	16.61	4.49	17.90	4.53	16.07	4.86
External thoughts	18.39	4.02	20.09	3.44	20.65	5.07	19.69	4.28

Note. ECS = Emotional Contagion Scale; IRI = Interpersonal Reactivity Index; TAS-20 = 20-Item Toronto Alexithymia Scale.

The aggregated AI score (M = 0, SD = 1.73), indicating amount of autism traits, was significantly negatively related to trait cognitive empathy (r [94] = - .54, p < .001) and self-regulation scores (r [94] = - .37, p < .001) scores. AI scores were positively related to alexithymia (r [95] = 0.55, p < .001) and not correlated with self-reported affective empathy (r [94] = - .19, $p \leq .068$; see Figure 5)[6]. After controlling for alexithymia in a linear regression model, AI scores still significantly predicted trait cognitive empathy, β = - 1.34, SE = 0.32, ΔR^2 = .13, t = - 4.13, p < .001 and self-regulation, β = - 1.26, SE = 0.44, ΔR^2 = .08, t = - 2.88, $p \leq .005$.

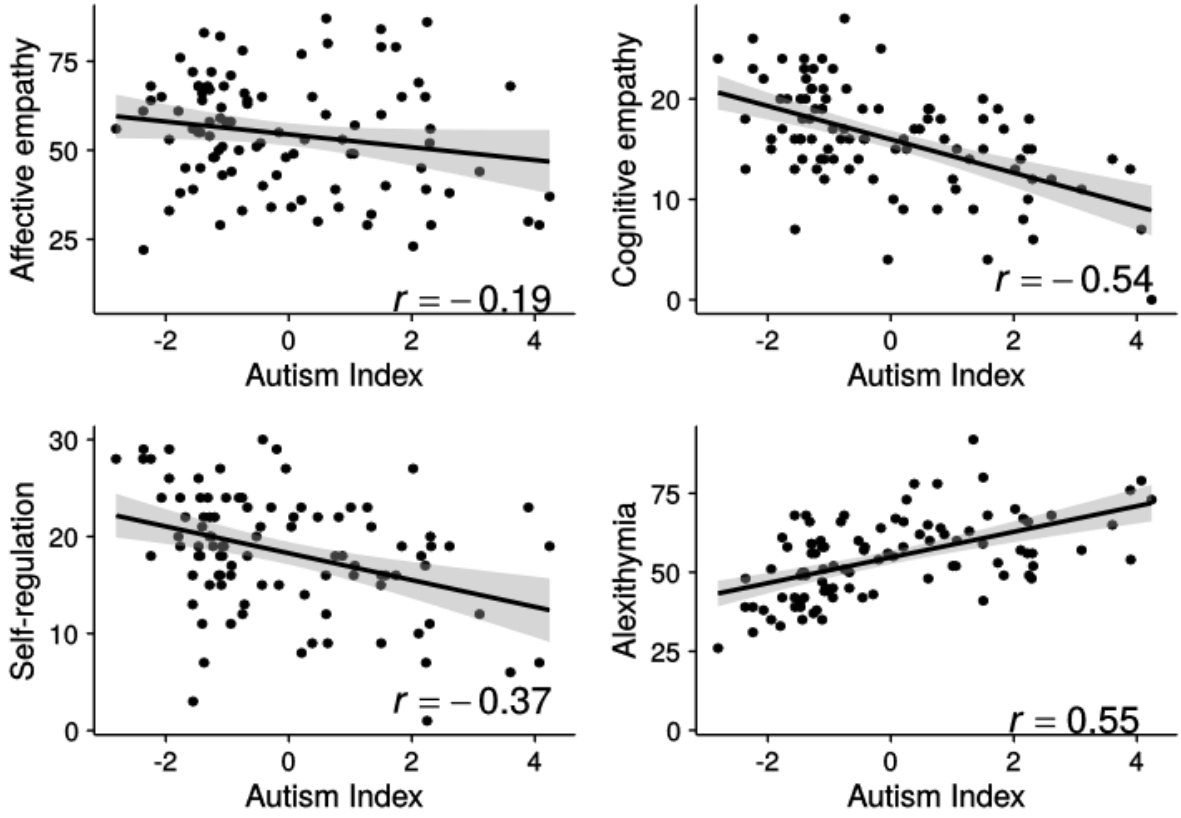

Figure 5. The correlation between amount of autism traits (AI) and affective and cognitive empathy, self-regulation and alexithymia. Shaded areas indicate the 95% confidence interval of the linear regression.

[6] To compare this analysis to the analysis using the total sample, affective empathy scores were also correlated with AQ scores. Similar to AI, there was no significant correlation between AQ scores and affective empathy, r [94] = - .19, $p \leq .053$.

Autism and performance cognitive empathy.

Emotion recognition. Descriptive statistics for emotion recognition accuracy and speed are shown in Figure 6 and Table 6. Speed was measured in two ways: time spent looking at the face before keypress (Response Time 1), and time spent selecting an emotion (Response Time 2). One participant responded considerably more slowly on the emotion recognition task than other participants, and was removed from all the emotion recognition analyses, leaving 97 participants. On average, happiness was recognised fastest and with the most accuracy. The response times until the first keypress (Response Time 1) were similar for the negative emotions. Average response times for the negative emotions at Time 2 ranged between 2.40 s (*SD* = 2.42) for Disgust and 4.07 s (*SD* = 4.49) for Fear. Emotion recognition accuracy and speed was predicted from type of emotion, AI and medication use. Linear mixed-effects models were run to predict average accuracy scores[7] over the three trials, and to predict response times.

[7]Average scores rather than accuracy per trial were used as binomial mixed-effects models of accuracy per trial did not converge.

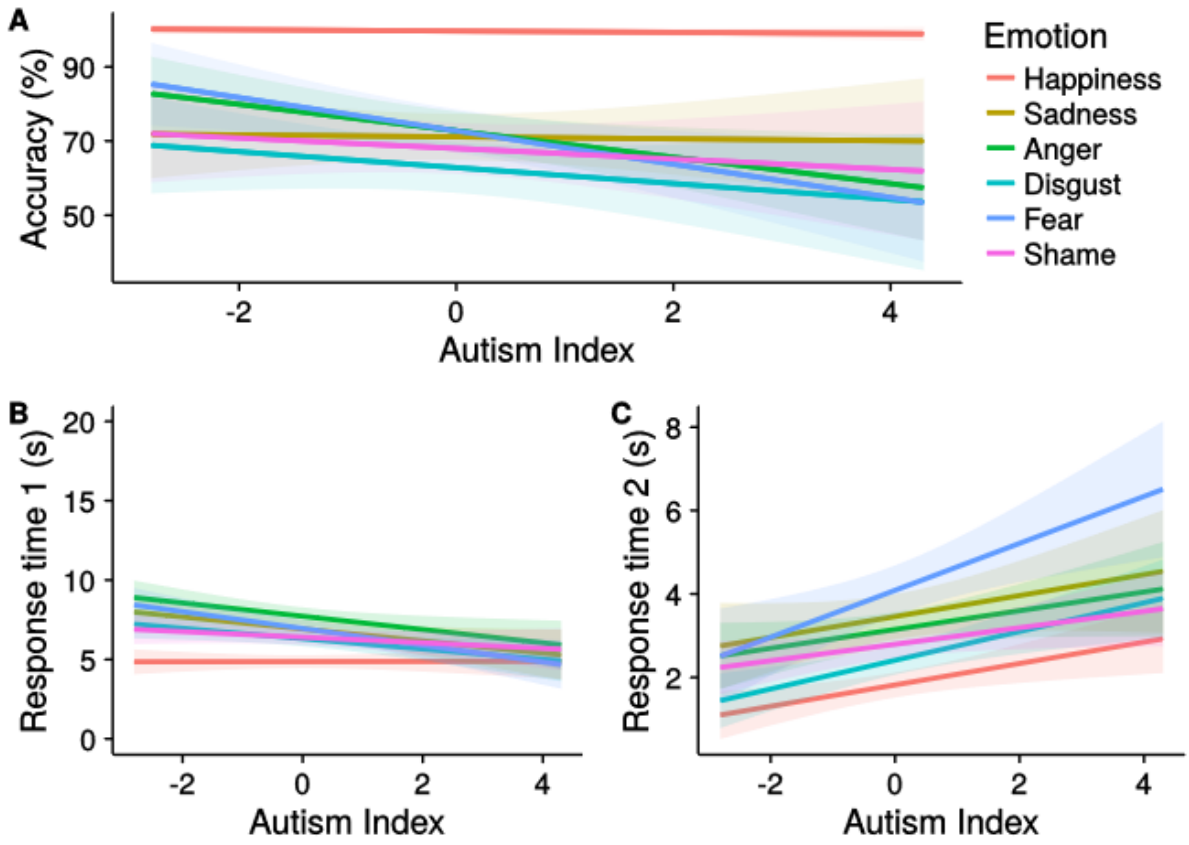

Figure 6. Emotion recognition accuracy (A) and speed by Autism Index (AI) and emotion. Response Time 1 (B) denotes time spent viewing the face until keypress; Response Time 2 (C) denotes time spent selecting an emotion. Shaded areas indicate the 95% confidence intervals around the prediction of the linear regressions.

Table 6

Emotion Recognition Accuracy and Response Times in Seconds

Autism traits	Emotion	Accuracy		Response time 1		Response time 2	
		M	*SD*	*M*	*SD*	*M*	*SD*
Low	Happiness	1.00	0.00	4.93	2.60	1.65	0.73
	Sadness	0.80	0.40	7.21	3.60	3.20	3.21
	Anger	0.80	0.40	7.96	4.02	2.96	2.70
	Disgust	0.65	0.48	6.77	3.02	2.13	1.41
	Fear	0.81	0.40	7.48	3.78	3.39	2.67
	Shame	0.69	0.47	6.52	3.00	2.64	1.89
Medium	Happiness	1.00	0.00	4.82	2.11	1.60	0.78
	Sadness	0.61	0.49	7.67	4.21	2.94	2.24
	Anger	0.74	0.44	8.81	3.67	2.77	2.38
	Disgust	0.65	0.48	6.57	2.50	1.96	1.12
	Fear	0.71	0.46	7.45	4.05	3.96	4.87
	Shame	0.70	0.46	6.72	3.13	2.49	1.55
High	Happiness	0.99	0.10	4.84	2.98	2.22	3.73
	Sadness	0.73	0.45	5.84	4.22	4.26	4.88
	Anger	0.65	0.48	6.35	4.95	3.73	3.40
	Disgust	0.59	0.50	5.57	4.03	3.15	3.76
	Fear	0.67	0.47	5.92	4.51	4.92	5.44
	Shame	0.66	0.48	5.95	3.83	3.27	2.97
Total	Happiness	1.00	0.06	4.87	2.57	1.81	2.21
	Sadness	0.71	0.45	6.93	4.08	3.45	3.61
	Anger	0.73	0.45	7.73	4.34	3.14	2.86
	Disgust	0.65	0.48	6.32	3.26	2.40	2.42
	Fear	0.73	0.45	6.97	4.16	4.07	4.49
	Shame	0.68	0.47	6.41	3.33	2.79	2.22

Accuracy. Emotion recognition accuracy was modelled in a random-effects model. The interaction between AI and emotion type was not significant and was removed from the final model. Overall, participants were significantly more accurate at recognising happiness than all other emotions, F (5, 480) = 25.69, $p < .001$, especially disgust (see Table 7). Post hoc tests showed no significant differences in accuracy between the other emotions. AI was negatively correlated with accuracy, $\boldsymbol{\beta} = -0.04$, $SE = 0.02$, F (1, 94) = 5.26, $p \leq .020$. Medication use did not significantly predict accuracy; F (1, 94) = 1.13, $p \leq .290$. The model was fit with a random intercept for ID, $\sigma^2_{ID} = 0.017$, $\sigma^2_{resid} = 0.06$.

Additionally, I performed a chi-squared goodness-of-fit test to see whether the low, medium and high autism traits groups selected the different emotions at the same frequency. There were no differences between the AI groups in their selection frequencies of the six different emotions, χ^2 (10, N = 1733) = 8.01, $p \leq .628$.

Table 7

Linear Random-Effects Model Estimates of Emotion Recognition Accuracy from Medication Use, AI and Emotion Type

Fixed effects	**β**	*SE*	*df*	*t*-value	Probability
Medication: Yes	0.05	0.04	94	1.06	.290
AI	- 0.04	0.02	94	- 2.29	.024
Sadness	- 0.29	0.04	480	- 7.95	< .001
Anger	- 0.27	0.04	480	- 7.47	< .001
Disgust	- 0.37	0.04	480	- 10.25	< .001
Fear	- 0.27	0.04	480	- 7.47	< .001
Shame	- 0.32	0.04	480	- 8.81	< .001

Note. Number of observations = 582, number of groups (ID) = 97. R^2_M = .16, R^2_C = .34. AI = Autism Index.

Response time. There was a significant interaction effect between AI and Emotion on Response Time 1, as well as significant main effects for AI and Emotion. Coefficient estimates suggest that the pattern of responses with increasing AI are mostly similar for all emotions: Higher AI scores were associated with *shorter* response times on anger, fear, sadness and disgust (all $p < .05$; see

Table 8 for exact figures). This association was greatest for fear (**β** = - 0.91, *SE* = 0.30, t (126) = - 3.04, $p \leq .003$). On average, participants had the fastest response times to happiness (all $p < .001$).

AI scores and Emotion also significantly predicted Response Time 2. On this analysis, there was no significant interaction between AI and emotion type. Higher AI scores were associated with *longer* response times for selecting the appropriate emotion. On average, participants selected happiness significantly faster than all other emotions (see

Table 8). The greatest time difference was between happiness and fear, **β** = 2.27, *SE* = 0.29, *t* (111.8) = 7.92, *p* < .001. Post hoc tests also showed that after happiness, disgust was recognised significantly faster than sadness (*p* < .001), and fear was recognised significantly slower than anger, disgust and shame (all *p*s < .001). The variance and correlation between the random effects are given in Table 9. Adding alexithymia to the models did not improve their fit.

Table 8

Linear Mixed-Effects Models of Emotion Recognition Response Time

Fixed effects	*SS*	*MS*	df_{effect}	df_{error}	*F*-value	Probability	
Response time 1							
Medication	12.41	12.41	1	94.97	1.27	.260	
AI	47.92	47.92	1	96.25	4.92	.030	*
Emotion	980.36	196.07	5	149.28	20.13	< .001	***
AI*Emotion	120.18	24.04	5	149.28	2.47	.040	*
Response time 2							
Medication	18.51	18.51	1	102.35	2.95	.09	
AI	82.25	82.25	1	100.59	13.12	< .001	***
Emotion	484.94	96.99	5	212.17	15.47	< .001	***
AI*Emotion	36	7.20	5	212.17	1.15	.34	

Table 8 (cont.)

Fixed effects	**β**	*SE*	*df*	*t*-value	Probability	
Response time 1						
Medication: Yes	- 0.52	0.46	94.97	- 1.13	.262	
AI	0.09	0.23	140.99	0.39	.698	
Sadness	2.06	0.32	108.89	6.37	< .001	***
Anger	2.86	0.30	116.71	9.45	< .001	***
Disgust	1.45	0.26	642.90	5.51	< .001	***
Fear	2.09	0.30	125.88	6.98	< .001	***
Shame	1.54	0.27	433.25	5.74	< .001	***
AI* Sadness	- 0.65	0.32	108.89	- 2.02	.046	*
AI* Anger	- 0.72	0.30	116.71	- 2.40	.018	*
AI* Disgust	- 0.57	0.26	642.90	- 2.15	.032	*
AI* Fear	- 0.91	0.30	125.88	- 3.04	.003	***
AI*Shame	- 0.31	0.27	433.25	- 1.14	.253	
Response time 2						
Medication: Yes	- 0.56	0.32	102.35	- 1.72	.089	
AI	0.53	0.17	200.49	3.10	.002	**
Sadness	1.64	0.30	100.16	5.54	< .001	***
Anger	1.33	0.25	142.25	5.25	< .001	***
Disgust	0.59	0.22	284.79	2.65	.009	**
Fear	2.26	0.29	111.77	7.92	< .001	***
Shame	0.98	0.23	240.62	4.30	< .001	***
AI* Sadness	- 0.01	0.30	100.16	- 0.03	.975	
AI* Anger	- 0.05	0.25	142.25	- 0.21	.831	
AI* Disgust	0.15	0.22	284.79	0.67	.503	
AI* Fear	0.52	0.29	111.77	1.83	.071	
AI*Shame	- 0.10	0.23	240.62	- 0.45	.657	

Note. Response time 1: R^2_M = .08, R^2_C = .32. Response time 2: R^2_M = .09, R^2_C = .39. AI = Autism Index.

* $p < .05$, ** $p < .01$, *** $p < .001$.

Table 9

Random Effects of the Linear Mixed-Effects Models of Emotion Recognition Response Time[8]

Random effects								
Group	*N*	Slope	Variance	Correlation				
Response time 1								
ID	97	(Intercept)	1.47					
		Sadness	3.62	- .01				
		Anger	2.37	.19	.69			
		Disgust	0.20	.75	.42	.65		
		Fear	2.20	.17	.67	.18	.06	
		Shame	0.47	.67	.60	.78	.75	.52
Residual	1746		9.74					
Response time 2								
ID	97	(Intercept)	0.48					
		Sadness	4.33	.19				
		Anger	2.03	.11	.99			
		Disgust	0.65	.32	.99	.98		
		Fear	3.78	.95	.38	.29	.48	
		Shame	0.81	.12	.99	1.00	.98	.29
Residual	1746		6.27					

Note. Random effects: ID (intercept); emotion (slope).

Faux pas. On average, participants scored 40 out of a possible 41 (*SD* = 3.69) on the control questions, 107 out of 120 (*SD* = 3.69) on all the Faux Pas questions, and 8 out of 10 (*SD* = 2.48) on the Faux Pas emotion recognition questions. Control question scores were

[8] The variances and correlations of the random effects are displayed so that the model validity can be evaluated. The variance of the intercept indicates the amount of variability in response time between individuals. The variance coefficient for each emotion indicates the amount of variability in response time within that emotion (e.g., sadness). The correlations indicated in the table show the correlation between the intercept and slope of each emotion.

correlated with AI, r (87) = - .35, $p \leq .0008$; hence, control accuracy was used as a control variable in the analyses of total Faux Pas and Faux Pas emotion recognition. The variance in both total Faux Pas and Faux Pas emotion recognition scores increased with increasing AI scores (see Figure 7). As heterogeneous presentation is an often-described part of ASD (Hoogenhout & Malcolm-Smith, 2014; Nuske, Vivanti, & Dissanayake, 2013), generalised least squares analyses with variance covariates were used to model the variance, rather than transforming the response variables to artificially reduce heterogeneity (Zuur et al., 2009). A non-linear increase in variance was allowed within the models.

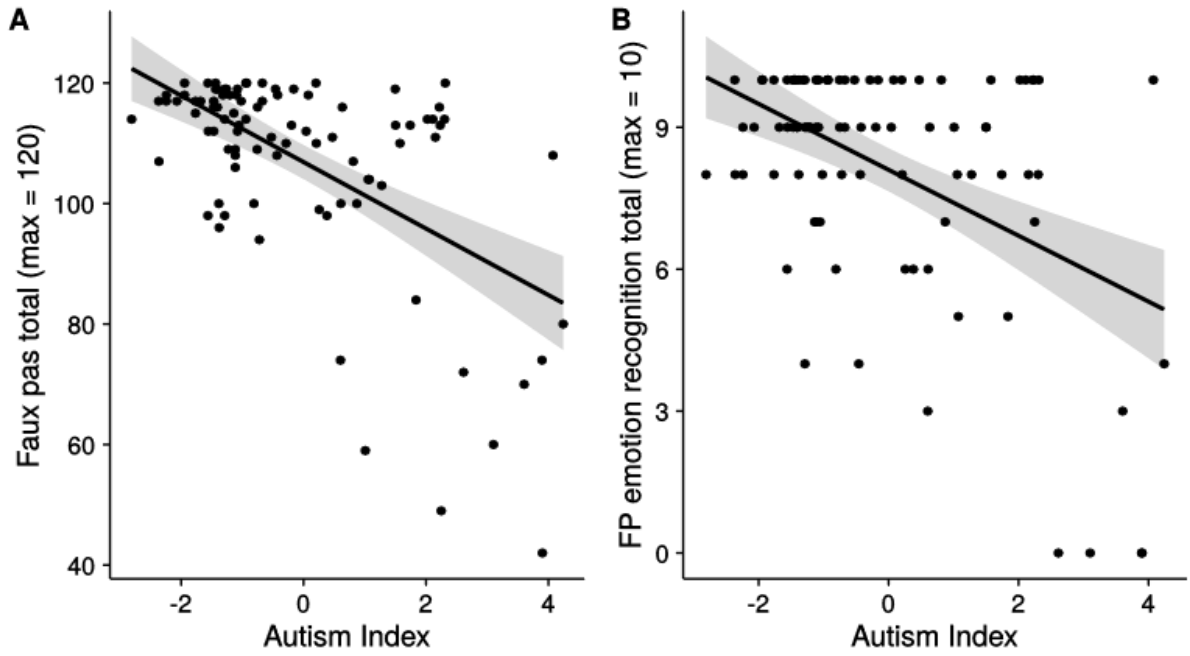

Figure 7. Autism Index scores were significantly negatively correlated with total Faux Pas scores (A) and with Faux Pas emotion recognition scores (B). The row-like patterning in B is because scores were integers from 1 to 10. Shaded areas indicate the 95% confidence interval of the linear regression. FP = Faux pas.

Faux Pas total score was predicted from control question accuracy, medication use and AI. A generalised least squares model with an exponential variance structure was fit as the variance in Faux Pas scores increased with increasing AI scores and with medication use (Figure 7). After inspection of the residuals, two influential values were removed and the regression was rerun, resulting in a better model fit (for model diagnostics, see Appendix P, Figure 28, p. 382). AI was significantly negatively correlated with Faux Pas scores, $\beta = -4.01$, $SE = 1.33$, $t\ (85) = -3.02$, $p \leq .003$, even after controlling for the effect of control question accuracy (see Table 10). Medication use was similarly negatively correlated with Faux Pas scores. Control question accuracy was positively correlated with Faux Pas scores. Adding alexithymia did not change the model fit. The original model with the influential values included is shown in Appendix P, Table 43, p. 381.

Table 10

Generalised Linear Model Coefficients of Faux Pas Total and Emotion Recognition Scores

Predictors	β	*SE*	df_{effect}	df_{error}	*F*-value	Probability	
FP Total [a]							
Control Score	4.13	1.53	1	85	15.55	.002	**
Medication	- 4.76	2.51	1	85	4.71	.033	*
AI	- 4.35	1.36	1	85	10.25	< .002	**
FP Emotion Recognition[b]							
Control Score	0.37	0.28	1	85	4.99	.028	*
Medication	- 0.88	0.47	1	85	3.32	.041	*
AI	- 0.37	0.25	1	85	2.20	.142	

Note. FP = Faux pas; AI = Autism Index.

[a] variance covariate exponent δ = 0.27. [b] variance covariate exponent δ = 0.24.

* $p < .05$, ** $p < .01$, *** $p < .001$.

A generalised least-squares model with an exponential variance structure was fit to predict emotion recognition on the Faux Pas task. The same two cases as in the previous analysis were identified as influential values, and these cases where removed from the final analysis (for model diagnostics, see Appendix P, Figure 29, p. 383). Control question accuracy was once again positively correlated with the Faux Pas emotion recognition scores, though this correlation was not significant on the marginal *t*-test, $t\ (85) = 1.33$, $p \leq .188$.

Medication use was negatively correlated with Faux Pas emotion recognition scores. AI scores were not significantly correlated with Faux Pas emotion recognition scores. The original model is again shown in Appendix P, Table 43, p. 381.

Correlations between performance cognitive empathy scores. The Faux Pas and emotion recognition scores were all significantly correlated with each other (see Table 11), except for the Faux Pas total score and emotion recognition accuracy, r (86) = .20, $p \leq .065$. Total Faux Pas and the reverse-scored emotion recognition Response Time 2 (where higher values now indicate better performance) were centred, scaled and aggregated to form a performance cognitive empathy score. These two tasks were chosen because they represent the most complex cognitive empathy tasks. Participants who were excluded in either the Faux Pas or emotion recognition analyses were not given a performance cognitive empathy total. Like its aggregates, the total performance cognitive empathy score was significantly correlated with AI (M = 0.20, SD = 0.99, r [86] = - .46, $p < .001$). This performance cognitive empathy aggregate was used as a predictor in subsequent analyses of affective and physiological states.

Table 11

Correlations Between the Different Performance Cognitive Empathy Measures

	ER-RT1	ER-RT2	FP-ER	FP Total
ER	.21*	- .23*	.25*	.20
ER-RT1		- .35***	.28**	.57***
ER-RT2			- .32**	- .53***
FP-ER				.63***

Note. ER = emotion recognition; RT = response time; FP = faux pas.

* $p < .05$, ** $p < .01$, *** $p < .001$.

Correlations between empathy facets. Trait affective empathy scores were significantly correlated with both trait cognitive empathy and self-regulation. Similar to the total sample, there was no significant correlation between trait cognitive empathy and self-regulation. Additionally, performance cognitive empathy was not significantly related to trait cognitive empathy, trait affective empathy or self-regulation (see Table 12).

Table 12

Correlations Between Empathy Measures

	Cognitive (T)	Cognitive (P)	Self-regulation
Affective	.58 ***	.07	- .45 ***
Cognitive (T)		.18	.01
Cognitive (P)			.17

Note. T = trait; P = performance.

* $p < .05$, ** $p < .01$, *** $p < .001$.

In summary, AQ scores were significantly negatively correlated with trait affective and trait cognitive empathy in the total sample. These correlations remained significant after alexithymia was controlled for. In the laboratory sample, AI scores were not correlated with trait affective empathy. As expected, AI scores were significantly negatively correlated with both trait and performance cognitive empathy and with self-regulation ability (Hypotheses I and II), even after controlling for alexithymia. Though there were significant correlations between trait affective empathy and self-regulation, and trait affective empathy and trait cognitive empathy, performance cognitive empathy was unrelated to all these facets.

Discussion

The aim of this preliminary study was to examine whether self-reported trait levels of cognitive empathy, affective empathy and self-regulation are correlated with autism traits once alexithymia is controlled for. Trait affective empathy, cognitive empathy and self-regulation scales were assembled from questions on the Emotional Contagion Scale and the Interpersonal Reactivity Index. The study examined empathy, alexithymia and autism traits in a large online sample, and in a smaller sample that came to the laboratory for additional autism and cognitive empathy assessments. In both samples, participants ranged from having high autism traits, in other words, having social-communication deficits and restricted, repetitive or stereotyped behaviours that met diagnostic criteria for ASD and impacted on daily functioning, to having low autism traits. Low autism trait individuals did not have psychiatric diagnoses and had minimal or no features of ASD. In between were individuals with some features of ASD, such as difficulties with maintaining conversations and peer relationships, as well as inflexibility of behaviour or thoughts, but who did not meet criteria for ASD.

In the next section, the correlations between empathy, autism traits and alexithymia in the two samples will be discussed. The discussion is followed by an overview of the internal consistency of the original questionnaires and the newly-constructed empathy facets (affective, cognitive and self-regulation).

Alexithymia

Autism traits were positively correlated with alexithymia. On average, the high AI group fell within the clinical range for alexithymia, and 48% of high AI participants met criteria for alexithymia. This result is in keeping with reports of high rates of alexithymia in autism spectrum disorder (Berthoz & Hill, 2005; Lombardo et al., 2007; Silani et al., 2008)

and the broader autism phenotype (Berthoz et al., 2013). Similar to this study, Berthoz and Hill (2005) reported that most individuals with autism have at least some alexithymia, and found "severe degrees of alexithymia" in 50% of individuals with ASD. Alexithymia was not limited to those with high amounts of autism traits, however, and was also found in individuals with low amounts of autism traits.

Dispositional Empathy

Trait affective empathy scores were significantly correlated with both trait cognitive empathy and self-regulation. As expected, trait cognitive empathy was negatively correlated with amount of autism traits. Similarly, autism traits were negatively correlated with self-regulation capacity in the laboratory sample. Individuals with ASD have previously reported higher levels of personal distress and less frequent and successful use of regulation strategies such as reappraisal than neurotypical individuals (Samson, Huber, & Gross, 2012). Individuals with ASD may rely more heavily on suppression as an emotion regulation strategy, which has been associated with reduced displays of positive affect and heightened negative emotions (Gross & John, 2003). As expected, autism traits were negatively correlated with trait cognitive empathy (Dziobek et al., 2007; Mazza et al., 2014; Rueda, Fernández-Berrocal, & Schonert-Reichl, 2014), even after controlling for alexithymia. There was no significant correlation between trait cognitive empathy and self-regulation.

The association between amount of autism traits and affective empathy differed between the samples. Autism traits were negatively correlated with trait affective empathy in the full sample, but not in the laboratory sample. One possible explanation for the differing results is that the correlation between ASD and affective empathy is very small, so that there was insufficient power to detect a significant effect in the laboratory sample. Given the size of the laboratory sample, the study had a 53% chance to detect a significant effect at the

effect size found in the total sample. However, trait cognitive and affective empathy has similar effect sizes in the total sample, and cognitive empathy was significantly correlated with autism traits in the laboratory sample, so lack of power is unlikely to be the only explanation for the nonsignificant correlation between affective empathy and autism traits in the laboratory sample. Another explanation is that reporting was biased in high ASD trait individuals, perhaps due to lack of insight into their own emotions, so that very high autism trait participants reported high affective empathy. This argument does not explain why a significant correlation was still found between cognitive empathy and autism traits, which should presumably be equally susceptible to impairments in insight. Another possibility is that, as I did not assess the total sample, it may have included individuals with undiagnosed and unreported psychiatric conditions that resulted in both higher AQ scores and lower affective empathy.

Previous self-report studies have found evidence of both diminished affective empathy (e.g., aan het Rot & Hogenelst, 2014; Demurie et al., 2011; Lombardo et al., 2007) and intact affective empathy in ASD (Dziobek et al., 2007; Rogers et al., 2006). Studies of physiological arousal, however, have more consistently shown intact affective empathy in ASD, including finding no difference in brain activation between ASD and neurotypical groups when observing others' pain (Hadjikhani et al., 2014). Others have found increased affective arousal to observing the pain of another in ASD (Gu et al., 2015). The overall picture suggests that affective arousal sharing is intact in ASD; however more, evidence from multiple sources is needed. Studies 2 and 3 examine the relationship between affective states and empathy at the physiological level.

Performance Cognitive Empathy

Performance cognitive empathy was measured using emotion recognition and faux pas tasks. Emotion recognition patterns corresponded to previous studies and were not correlated with amount of autism traits. That is, all participants recognised happiness the fastest and with the most accuracy. All the negative emotions took longer to recognise than happiness, which was used as the baseline. Fear took longest to recognise. Accuracy rates for sadness, anger, shame and fear were comparable, as was recognition speed for sadness, anger, shame and disgust. These results in adolescence and adulthood mirror the development of emotion recognition in children. The recognition of fear and disgust typically develops slightly later in childhood than the recognition of happiness or sadness does (Durand, Gallay, Seigneuric, Robichon, & Baudouin, 2007; Rump, Giovannelli, Minshew, & Strauss, 2009).

Autism traits were negatively correlated with emotion recognition accuracy across all emotions, even after controlling for alexithymia. These results correspond to recent meta-analyses of emotion recognition in ASD whose authors concluded that individuals with ASD have problems with emotion recognition across a range of emotion expressions (Lozier, Vanmeter, & Marsh, 2014; Uljarevic & Hamilton, 2012). These authors concluded that emotion recognition deficits are pervasive and not limited to certain subgroups of ASD. The discrepancy between the significant differences in my study and the non-significant results of other studies, which have predominantly focused on emotion recognition in children with ASD, may be because individuals with ASD show little improvement in emotion recognition with age, so that group differences become more marked in adulthood (Rump et al., 2009). Unlike previous studies (Cook et al., 2013; Lane et al., 1996, 2000), I did not find that alexithymia was correlated with emotion recognition. Differences may be due to different methodologies: Lane and colleagues (1996, 2000) focused on emotion recognition in social stories in their studies, not facial emotion recognition. Cook and colleagues (2013) used

morphed facial expression, but presented cross-morphed emotion stimuli where participants only had to distinguish between two emotions at a time (anger versus disgust and fear versus surprise). Their task is thus subtly different from the one used in the current study: First, participants only had to choose between two emotions at any time, making it easier for their ASD participants; secondly, participants had to choose the point at which one emotion changes into another, rather than choosing which one emotion was shown on the face. These different task demands may require somewhat different skills.

Greater autism traits were associated with shorter response times on seeing the emotion (i.e., Time 1, the time taken to recognise the emotion). This analysis included response times for both accurate and inaccurate responses. It was decided not to remove inaccurate responses from the analyses because of the significant correlation between autism traits and accuracy. Removing inaccurate responses would have inordinately removed participants with high amounts of autism traits from the analyses. Participants with higher levels of autism traits may have been more likely to perceive an emotion on the neutral starting expression, which could explain the shorter response times in these participants. Durand and colleagues (2007) has found that young children, who are not yet proficient in recognising emotions, are more likely than adults to ascribe an emotion – usually happiness or sadness – to a neutral expression. Participants with greater amounts of autism traits, who are less adept at accurately recognising emotions, may do the same. There were no group differences in the frequency at which each emotion was chosen, so if high autism trait participants were ascribing an emotion to the neutral expression, they did not preferentially pick a specific emotion above another. Alternatively, it is possible that participants with high amounts of autism traits were more likely to try to guess the emotion, and thus spent less time observing the videos before keypress. Besides autism traits, the type of emotion also predicted the amount of time participants spent looking at the video before recognising the

emotion: All the negative emotions took longer to recognise than happiness, which was used as the baseline. Response latency at Time 2, when participants had to decide on and select an emotion, was negatively correlated with amount of autism traits. This result is consistent with the hypothesis that individuals with more autism traits have more difficulties in recognising facial expressions of emotion. In summary, autism traits were negatively correlated to both accuracy and speed of emotion recognition when selecting an emotion. Participants with more autism traits may be more likely to try to guess the emotion quickly or to ascribe emotions to neutral expressions.

Cognitive empathy does not only encompass the ability to read visible affective expressions, but also involves the ability to imagine the emotional state of someone who is not present, or of a fictional character. The faux pas task assesses participants' perception of social missteps, as well as their understanding of the emotions of the character that was accidentally slighted. As such, it assesses a more complex aspect of cognitive empathy than the emotion recognition task. Amount of autism traits was significantly negatively correlated with the ability to recognise social faux pas after controlling for accuracy in answering the control questions. This result suggests that differences in performance on the faux pas questions were not primarily related to comprehension, attention or working memory difficulties in participants with higher amounts of autism traits.

Besides identifying social faux pas and explaining why they were awkward, participants had to predict the story characters' emotional responses to the faux pas. Though amount of autism traits was not significantly correlated with faux pas emotion recognition scores, medication use was. As medication use was significantly correlated with amount of autism traits, it may be an indicator of ASD in this analysis rather than a true effect of medication. Of the participants taking medication, 77% had high amounts of autism traits. However, a negative effect of medication on faux pas performance cannot be ruled out.

Medications such as antipsychotics have been implicated in cognitive empathy deficits. In this study, 4% of participants were on antipsychotics, mainly risperidone. Previous studies of schizophrenia have reported that individuals on risperidone and typical antipsychotics perform worse on cognitive empathy tasks than individuals on other antipsychotics such as clozapine and olanzapine (Savina & Beninger, 2007). However, not all studies have found negative effects (Kucharska-Pietura & Mortimer, 2013; Sergi et al., 2007). It is also not clear whether risperidone worsens cognitive empathy or whether other antipsychotics improve cognitive empathy in schizophrenia more than risperidone does (Savina & Beninger, 2007). To my knowledge, there are no published studies of the effects of medication on cognitive empathy in ASD. Furthermore, antipsychotics reportedly do not affect the core social features of ASD (Anagnostou & Hansen, 2011; Francis, 2005). It is therefore more likely that the significant correlation between medication and faux pas performance can be attributed to ASD. Several previous studies have shown that individuals with ASD are less able to accurately identify faux pas (Baron-Cohen et al., 1999; Spek, Scholte, & Berckelaer-Onnes, 2009), and perform worse on the emotion recognition questions than neurotypical individuals (Zalla, Sav, Stopin, Ahade, & Leboyer, 2008).

Questionnaire Reliability and Validity

Overall, the internal consistencies of the questionnaire subscales were good. However, there were some individual items which were problematic. AQ item 30 ("I don't usually notice small changes in a situation or a person's appearance") was negatively correlated with the rest of the items in both AQ versions in the total and laboratory samples. The original AQ study also reports that control participants scored higher on this item, as well as on item 29 ("I am not very good at remembering phone numbers") than participants with ASD (Baron-Cohen et al., 2001). In the current study, item 29 was not negatively correlated with the other scale items, but had a low correlation to the other items, similar to

previous findings (Hoekstra et al., 2010; Wakabayashi, Baron-Cohen, Wheelwright, & Tojo, 2006). These two items seem to test general attention and memory skills rather than traits associated with the core features of ASD, and do not seem to be valid indicators of ASD. Both of these items were left out of a subsequent short form of the AQ (Hoekstra et al., 2010; Kloosterman, Keefer, Kelley, Summerfeldt, & Parker, 2011). However, I took a conservative approach in this study and used all the original items to calculate AI scores.

The TAS-20 scale for alexithymia had low internal consistency on its External Thoughts subscale. The internal consistency for the External Thoughts subscale was also low-to-moderate in the original publication of the TAS-20 (Bagby, Parker, et al., 1994), and ranged from very low to acceptable in translated versions of the TAS-20 (see Taylor et al., 2003, for a summary). Three of the items in this subscale were problematic: Item 5 ("I prefer to analyze problems rather than just describe them") had a negative correlation with the rest of the items, and items 18 ("I can feel close to someone, even in moments of silence") and 20 ("Looking for hidden meanings in movies or plays distracts from their enjoyment") had low correlations with the other items. These results may be due to cultural differences in describing emotion, or to the inherent problem of adequately measuring difficulties in self-awareness with a self-report scale (Lane, Sechrest, & Riedel, 1998). The TAS-20 has been translated and used in several cultural contexts, including Korean and Indian populations (Lee et al., 2010; Pandey, Mandal, Taylor, & Parker, 1996), where the authors found that the factor structure was adequate. However, most studies have found poor inter-item correlations on some of the items; particularly those in the External Thoughts subscale (Haviland, 1996; Kooiman, Spinhoven, & Trijsburg, 2002). Thus, the current study's findings may reflect problems with the questionnaire rather than peculiarities of this South African sample. Seeing that the overall internal consistency on the TAS-20 was good, no items were removed from the calculation of the final TAS-20 alexithymia score. All three subscales, External Thoughts,

Identifying Feeling and Describing Feelings were used to keep the results of this study comparable to those of previous studies.

The two empathy questionnaires, the ECS and the IRI, had adequate to good internal reliability, and no individual items with very low or negative correlations with the other items. Items from the IRI and ECS were then divided into three scales representing affective empathy, cognitive empathy and self-regulation based on theory. Trait affective empathy questions assessed the tendency to share or 'catch' the emotions of others (e.g., "I get filled with sorrow when people talk about the death of their loved ones", whereas cognitive empathy questions assessed the ability to understand others' mental states, and the tendency to take the perspective of other people in order to better understand them (e.g., "I try to look at everybody's side of a disagreement before I make a decision"). The items in the self-regulation subscale all came from the IRI's Personal Distress subscale. They were labelled as self-regulation here because their content really addresses the ability to function well under difficult circumstances (i.e., the ability to self-regulate), rather than an emotional state *per se*. For example, two items from the self-regulation subscale are "I am usually pretty effective in dealing with emergencies" (positively keyed) and "I tend to lose control during emergencies" (negatively keyed). These questions first and foremost assess regulatory ability and executive functioning, rather than emotional disposition.

The newly formed affective empathy, cognitive empathy and self-regulation scales had good internal consistencies in the both the laboratory and total samples. Some individual items had moderately low correlations with other scale items in the laboratory sample, though the correlations were still within conventional standards. IRI 7 ("I am usually objective when I watch a movie or play, and I don't often get completely caught up in it"), IRI 18 ("When I see someone being treated unfairly, I sometimes don't feel very much pity for them") and ECS 10 ("I tense when overhearing an angry quarrel") had low correlations with the affective

scale total. Similarly, IRI 3 (“I sometimes find it difficult to see things from the "other guy's" point of view”) and 8 (“I try to look at everybody's side of a disagreement before I make a decision”) had low correlations with the cognitive empathy total, and IRI 10 (“I sometimes feel helpless when I am in the middle of a very emotional situation”) had a low correlation with the self-regulation total. These items were not excluded, as their inter-item correlations fell within the recommended acceptable standards (Briggs & Cheek, 1986). The affective empathy, cognitive empathy and self-regulation scale scores were correlated with alexithymia, gender and autism traits, and were used in Studies 2 and 3 to predict state affective and physiological responses.

As some of the measures, such as the Emotional Contagion Scale, have not been used in a South African context before, performance on the scales were correlated with gender, which is known to be associated with empathy in other samples. Studies consistently find higher empathy in females than males, not only in self-report measures, but also in performance cognitive empathy when participants are not specifically incentivised (Klein & Hodges, 2001; R. L. Smith & Rose, 2011) and in psychophysiological and developmental measures of empathy. For example, studies have found that females have greater amplitude and longer-latency brain responses to observing others’ pain (Han et al., 2008; Yang, Decety, Lee, Chen, & Cheng, 2009), and faster development of perspective taking skills (van der Graaff et al., 2014). Similar to previous findings (Davis, 1980; Derntl et al., 2010; Eisenberg et al., 1994; Rueckert & Naybar, 2008), females scored higher on self-reported trait cognitive and affective empathy in this study. Females in this sample reported poorer trait regulation of emotion during distressing situations. This corresponds to previous reports that girls have greater empathic concern but also greater personal distress in friendships than boys (R. L. Smith & Rose, 2011; van der Graaff et al., 2014). Similarly, the alexithymia and autism quotient scores were consistent with international performances on the scales. Males reported

significantly higher levels of alexithymia than females, as has been found in previous studies (Kokkonen et al., 2001; Lane et al., 1998; Parker, Taylor, & Bagby, 2003). In keeping with the gender profile of ASD (Baron-Cohen et al., 2001), males also had significantly more autism traits than females. Furthermore, as has been reported previously in this chapter, autism traits and alexithymia were positively correlated. Thus, although not all the questionnaires used in this sample have been used in a South African context before, the internal consistencies of the questionnaires were good, and correlational results are consistent with international findings. These results support the conclusion that the questionnaires reliably and validly measured empathy in this sample. The limitations specific to Study 1 are discussed next. Limitations that apply to all the studies are discussed in Chapter 8.

Limitations

Self-report measures of emotion and behaviour are prone to distortions of memory and social desirability. Self-report can also be difficult to use in a population group that has difficulties with identifying and describing emotions, and with social-communication in general. However, all the self-report measures used in this study have previously been used successfully in studies with participants with ASD (e.g., Bird et al., 2010; Dziobek et al., 2007; Minio-Paluello, Lombardo, Chakrabarti, Wheelwright, & Baron-Cohen, 2009). Furthermore, the limitation of self-reporting of emotion is addressed in Studies 2 and 3, where physiological measurements of affective arousal are used to supplement subjective reports.

Participants in the total sample filled in an online questionnaire. Participants who reported neurological or psychiatric conditions were excluded from the analyses, but unreported mood or personality disorders may have influenced responses on the empathy and autism questionnaires. For example, participants with schizophrenia may score higher on

both the empathy and autism questionnaires because of impairments in cognitive empathy (Montag et al., 2011), and depression has been related to poorer cognitive empathy and increased personal distress (Schreiter, Pijnenborg, & aan het Rot, 2013). This limitation is true of all self-report studies, and is not limited to the current study. It was addressed in the laboratory sample, where participants with overt psychiatric disorders where excluded after the ADOS-2 assessment.

Processing speed was not assessed in the laboratory sample. Differences in processing speed between low and high autism trait participants could have affected the timed tasks of emotion recognition; specifically, participants with slower processing speed may have taken longer to select the appropriate emotion. However, multiple measures were used to assess performance cognitive empathy, not just response time, and processing speed should not have affected the other measurements (which were not timed).

Summary and Conclusion

The aim of this study was to examine the hypothesis that, whereas trait levels of cognitive empathy and self-regulation are negatively correlated with autism traits, affective empathy is not correlated with autism. Empathy, alexithymia and autism traits were measured via self-report in a large online sample. Part of this sample was invited to the laboratory for further autism and cognitive empathy assessment and to participate in Studies 2 and 3.

As expected, amount of autism traits was significantly negatively correlated with both trait and performance cognitive empathy. Amount of autism traits was also negatively correlated with self-regulation ability in the laboratory sample. This result is in keeping with previous studies that have reported less successful emotion reappraisal and greater use of less beneficial regulation strategies such as suppression in ASD (Konstantareas & Stewart, 2006; Samson et al., 2012), which may ultimately heighten personal distress. However, from the

self-report there remains some uncertainty in whether autism traits are correlated with affective empathy: Autism traits were not correlated with affective empathy in the laboratory sample, but were negatively correlated with affective empathy in the total sample, as would be predicted from the global empathy deficit hypothesis. Neither set of results support the empathy imbalance (A. Smith, 2009) theory of autism that predicts that individuals with autism have increased rather than decreased affective arousal. However, autism traits were also significantly positively correlated with alexithymia, which may have influenced these individuals' abilities to answer about their internal states. Thus, Studies 2 and 3 were designed to investigate affective empathy at different levels of analysis. Specifically, measurement of physiological arousal gives insight into affective states without having to rely on self-report. Study 2 examines the possible associations between affective empathy, self-regulation and autism traits by measuring autonomic reactivity, muscle reactivity and subjective reports of empathic concern or personal distress to witnessing others' physical pain.

CHAPTER 6.

STUDY 2: EMPATHY FOR SENSORY PAIN

> When we see a stroke aimed, and just ready to fall upon the leg or arm of another person, we naturally shrink and draw back on our leg or our own arm; and when it does fall we feel it in some measure… The mob, when they are gazing at a dancer on the slack rope, naturally writhe and twist and balance their own bodies, as they see him do. (A. Smith, 1790, p. 5)

Study 1 found that autism traits were negatively correlated with self-regulation and cognitive empathy, but were not consistently correlated with affective empathy. The focus of Study 2 was to expand these findings to the physiological level. Given the results of Study 1, I predicted that, in comparison to individuals with low autism traits, individuals with more autism traits would report similar levels of empathic concern but heightened personal distress to images of others in pain. At the physiological level, heightened personal distress should be reflected in heightened muscle reactivity, heightened sympathetic arousal and reduced parasympathetic arousal to the images of pain. At the cognitive level, potential contributors to heightened affective, muscular and autonomic reactions are self-regulation and cognitive empathy deficits, as were reported in Study 1 in participants with high autism traits. In turn, self-regulation and cognitive empathy deficits may be caused or exacerbated by tonic autonomic dysregulation, as predicted by the neurovisceral integration and polyvagal theories. Study 2 therefore aimed to explore (1) the association between resting state autonomic arousal and dispositional empathy measures, as well as (2) the association between resting state autonomic arousal and autism traits. Furthermore, Study 2 explored (3) the contributions of resting state autonomic arousal and dispositional empathy to state

affective responses (i.e., empathic concern and personal distress) while watching the pain videos.

Methods

Design

The study followed a multilevel correlational design, investigating within-subject changes in physiological and subjective affective states, and correlations between participants' autism traits and their empathic responses. Participants were shown videos of either painful or non-painful stimulation of a target. Muscle amplitude and slope, heart rate, SCL and pre-ejection period were predicted from video condition and AI scores. (1) Self-reported affective responses to the videos and (2) perceived pain intensity/unpleasantness were used to predict physiological arousal.

Participants

Of the 98 participants who formed the laboratory sample in Study 1 (see *Chapter 4, Participants*, p. 50), 95 completed Study 2. Due to equipment failure, EMG data were available for 93 participants and skin conductance and cardiac data for 92 participants. Self-report data were available for all participants.

Materials and Measures

Previously reported measures. AI scores, as calculated from ADOS-2 and AQ scores in Study 1, were used as an indicator of amount of autism traits. For dispositional empathy, the trait affective empathy, trait cognitive empathy, and trait self-regulation aggregates calculated in Study 1 were used (see Table 5, p. 84). However, as trait and performance cognitive empathy were not correlated in Study 1, performance cognitive empathy (rather than trait cognitive empathy) was used as the primary indicator of cognitive

empathy in the analyses. Performance scores were judged as more reliable measures of cognitive empathy than self-report measures. Total scores on the 20-item Toronto Alexithymia Scale (TAS-20) were used to indicate alexithymia, as was done in Study 1.

Video stimuli. Four types of video clips, lasting approximately 4 s each, were presented on a computer screen. The videos showed a static left hand, a needle deeply penetrating a hand, a cotton swab gently touching a hand (Bos, Montoya, Hermans, Keysers, & van Honk, 2015), and a needle deeply penetrating a tomato (Minio-Paluello, Baron-Cohen, et al., 2009). The videos were mirrored to show a left hand instead of a right hand (see Figure 8), as EMG responses were measured from the participants' left hands (see *Procedure,* p. 118, for more details). The videos have been used in several previous studies to measure empathy-related affective states and muscle-evoked potentials, as well as autonomic responses such as pupil dilation (Avenanti et al., 2005; Azevedo et al., 2013; Bos et al., 2015; Minio-Paluello, Lombardo, et al., 2009).

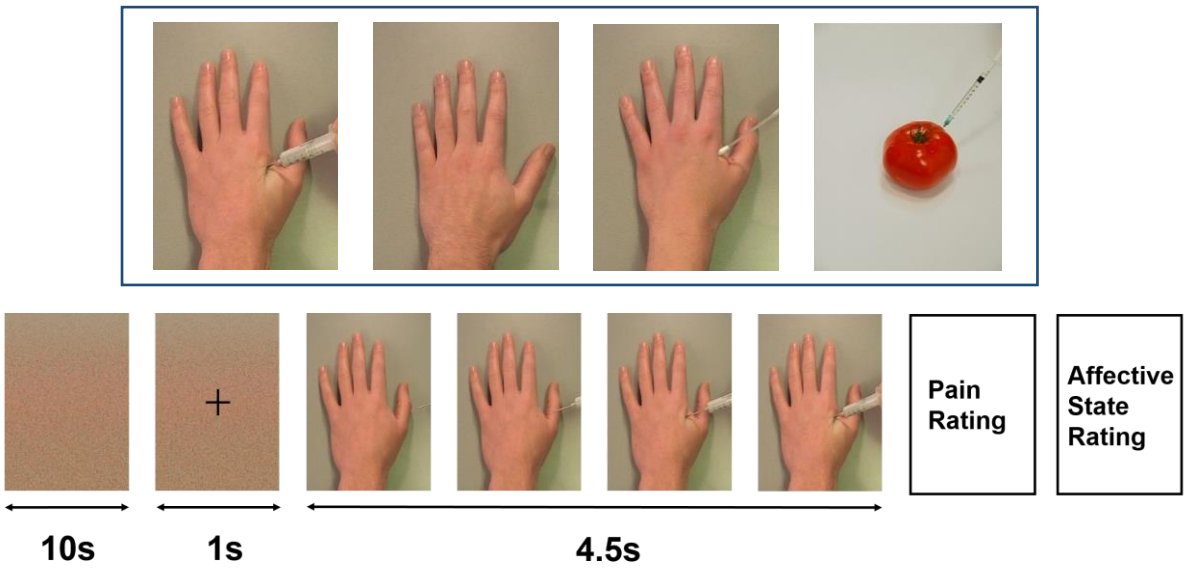

Figure 8. Empathy for sensory pain stimuli. The top row shows the final clip from each of the four video conditions: a needle stabbing a hand (top, far left), a static hand (top, centre left), a cotton swab gently touching a hand (top, centre right), or a needle penetrating a tomato (top, far right). The bottom row shows the order of stimulus presentation. Each 4.5 s video was preceded by a 1 s fixation cross and followed by questions asking participants to rate the pain intensity/unpleasantness and their affective state. Adapted from "Absence of Embodied Empathy During Pain Observation in Asperger Syndrome" by Minio-Paluello, Baron-Cohen, Avenanti, Walsh and Aglioti, 2009, *Biological Psychiatry*, *65*, p. 57. Copyright 2015 by Elsevier and the Society of Biological Psychiatry.

Affective states and perceived pain. Levels of empathic concern and personal distress were calculated from aggregates of 13 different emotional state scores (see Appendix N, p. 376), as described in Batson et al. (1997). I excluded the question, "How warm did you feel?" because of the likelihood of participants responding based on literal rather than emotional warmth (Batson et al., 1997). Affective states and perceived pain (both intensity

and unpleasantness) were rated on 7-point Likert scales from *not at all* to *extremely*. Participants were offered definitions of all the affective states. Besides absolute affective state and pain perception scores, difference scores between the painful and non-painful conditions were calculated to get a measure of sensitivity of affective responding and pain perception. Difference scores ranged from - 6 (reduced affective response/perceived pain during the pain condition) to + 6 (heightened affective response/perceived pain during the pain condition).

Batson and colleagues reported good internal consistency for the empathic concern (.85) and personal distress (.93) subscales. Similar affective state and perceived pain scales have been used in previous studies with South African child and adult samples (Cowell et al., 2016; Meiring, Subramoney, Thomas, Decety, & Fourie, 2014); however, the studies did not provide reliability estimates. The list of questions comprising the empathic concern and personal distress subscales, and their definitions, are given in Appendix N.

Electromyogram (EMG). EMG data were recorded for two muscles in the left hand: The First dorsal interosseous (FDI; the muscle targeted on the video) and the Abductor digiti minimi (ADM; control muscle). The reference electrode was placed on the left wrist. Figure 9 illustrates the electrode placement. Stimulus-evoked EMG activity was scored as the change in activity from a 1 s prestimulus baseline and was averaged over 200 ms periods from 0 to 4.4 s to create a reasonable number of measurements for subsequent calculations (similar to Dimberg & Thunberg, 2012; Dimberg et al., 2000). Trials that had EMG activity above 8 µV during the baseline period or activity above 30 µV or below -30 µV during stimulus presentation (0.20% of data) were excluded to prevent large resting state differences and extreme values that cannot be considered as involuntary reactions (Reicherts et al., 2012). Two measures of EMG activity were used. The average EMG amplitude (relative to

baseline) in the 200 ms after the period of greatest pain in the videos, time 4.0 – 4.2 s, was calculated as a measure of response magnitude, and compared to the average EMG amplitude at time 0 – 200 ms. To get an indication response latency, the slope of the average EMG activity over consecutive 200 ms periods was calculated (Malmo & Davis, 1956; Malmo & Malmo, 2000).

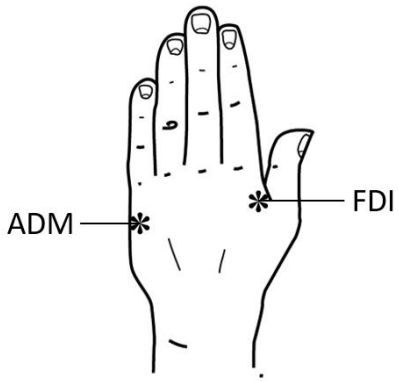

Figure 9. Placement of the electrodes to measure activity over the First dorsal interosseous (FDI) and Abductor digiti minimi (ADM) muscle areas.

Autonomic activity. Heart rate, pre-ejection period, SCL and RSA were measured during a 2-minute resting state baseline. Heart rate and pre-ejection period were measured and averaged over each of the 4 s videos. Because of the longer response latency of SCL, SCLs were recorded over an 8 s period starting from pain onset and compared to the first 2 s of the stimuli, before pain onset started, which acted as the baseline. RSA was only recorded during resting state, as the stimuli were not long enough for RSA measurement during the experiment. As recommended, EKG artefacts were removed (3.58% of data) and corrected using cubic spline interpolation of missed interbeat intervals (Berntson & Stowell, 1998; Vrije Universiteit, 2015). According to international standards (Sherwood et al., 1990; Willemsen et al., 1996), beats with bad ICG signal quality were automatically detected and

removed from individual complexes (0.38% of data). Additionally, ensemble-averaged ICG complexes were manually inspected and those with poor signal quality were discarded (2.20% of data). One SCL epoch was shortened due to movement artefact (Liew et al., 2003).

Procedure

The experiment was conducted in a temperature and lighting-controlled room. Participants were asked not to smoke, eat, exercise, or drink caffeinated beverages or alcohol for 2 hours prior to the experiment. On arrival at the laboratory, the VU-AMS and ActiveTwo electrodes were fitted. Participants were separated from the researcher by dark, opaque curtains. The researcher could monitor whether participants were paying attention to the stimuli, and were not moving unduly, through an opening between the curtains. Participants were asked to remain seated and rest their left hand (to which the EMG and skin conductance electrodes were attached) on the table throughout the experiment. Participants were further asked to refrain from talking or moving excessively during tasks. The left hand was chosen to monitor EMG responses so that participants were free to use the keyboard with their right hand. Before starting the experiment, participants listened to music (Clair de Lune, Schmalfuss, 2010) for five minutes, after which two minutes of resting state data were collected while participants sat with their eyes closed. The music served as time for participants to relax and get used to the electrodes (Fridlund & Cacioppo, 1986), as well as time to get better electrical contact between the electrodermal electrodes and the sweat gland ducts.

The video clips were presented using E-Prime 2 (Psychology Software Tools, Pittsburgh, PA) on a 19-inch, 4:3 aspect ratio monitor, positioned approximately 65 cm away from the participants. The pain videos were presented in three blocks of 12 videos each (3 videos of each of the conditions). Videos were randomised within each block. Between trials,

participants viewed 10 s luminance-matched scrambled static images to reduce potential muscular and arousal responses to changes in luminance (Lamm et al., 2007, 2008). Stimuli were preceded by a 1 s display of a centred fixation cross. To control for attention, participants answered a multiple-choice control question after each block of videos ("What gender was the hand?"; "What was the age of the hand?"; "Which object was not used in the videos?"). Once EMG recording was completed, participants were shown each image again and were asked to rate the intensity and unpleasantness of the pain shown in the video, as well as their level of empathic concern and personal distress.

Data Analysis

Descriptive statistics and zero-order correlations were calculated for the physiological and subjective data. For the physiological measurements, responses to the same condition were averaged within a block. The static hand condition was used as the comparison group in each of the analyses. First, preliminary linear random-effects models with participant ID as the random intercept were done to assess whether the stimuli elicited significant changes in the various physiological indices. Second, separate mixed-effects models were done to predict pain perception (i.e., pain intensity and unpleasantness) and subjective affective state (i.e., empathic concern and personal distress) from amount of autism traits (AI), self-regulation and performance cognitive empathy. Models were built for absolute affective state and pain perception scores, as well as difference scores between the painful and non-painful conditions. In both sets of models, the outcome variable for pain perception was rating (out of 7, where 7 = *extreme unpleasantness/intensity*), and pain unpleasantness versus pain intensity was entered as a binary predictor variable (fixed effect). Thus, except in cases where there was a significant interaction, pain perception refers to both pain unpleasantness and pain intensity. Similarly, the outcome variable for the affective state responses was rating (out of 7, where 7 = *extreme concern/distress*) and state type (concern versus distress) was coded as

a binary predictor variable. Thus, affective state refers to both empathic concern and personal distress. Where graphs of affective state are presented, the scores represent the average of the empathic concern and personal distress scores. Likewise, pain perception ratings in graphs represent the average pain intensity and unpleasantness scores.

Third, a series of linear mixed-effects models were run to model the effect of condition (type of video), alexithymia, self-regulation, performance cognitive empathy and AI on muscle activity and physiological arousal (muscle activity and slope, pre-ejection period, SCL, heart rate). The analyses with muscle activity also included muscle type (FDI, ADM) as a fixed effect. Block order (one to three), medication use (yes/no) and alexithymia were included as control variables in all the above analyses. Last, resting state cardiac arousal variables (cardiac vagal control, pre-ejection period and heart rate) were used to predict AI scores, trait affective empathy, trait and performance cognitive empathy, and trait self-regulation in separate linear regressions. Baseline arousal was furthermore used as a control variable in each of the autonomic arousal models. To calculate resting state cardiac vagal control, RSA was predicted from respiration rate and tidal volume. The residuals of that regression, free from the effects of respiration, were used as an indicator of cardiac vagal control. All analyses were preceded by an investigation of the distribution of the data and inspection for outliers. Models were also examined for multicollinearity, outliers and influential values, heteroscedasticity, dependence of errors, and other patterning of the residuals. Continuous predictors were centred and scaled ($M = 0$, $SD = 1$).

To model pain perception responses, participant ID was used as the random intercept, with condition and perception type (intensity, unpleasantness) and their interaction as random slopes (as recommended by Barr et al., 2013). To model affective state, participant ID was used as the random intercept, with condition and state type (personal distress, empathic concern) and their interaction as random slopes. In the models of muscle activity, participant

ID was used as the random intercept with muscle type, condition and the interaction between muscle and condition as random slopes. For the physiological arousal models (pre-ejection period, heart rate, SCL), participant ID was used as the random intercept with condition as the only random slope. If a model did not converge, an iterative simplification process was followed (Bates, Kliegl, Vasishth, & Baayen, 2015): First, a simpler random slopes structure without an interaction was tried, and if this model also did not converge, a nested intercept structure (e.g. participant ID and condition within participant ID as intercepts) was attempted. Where within-group variance was zero and model fit indices indicated a poor fit with a more complex model, responses were aggregated across conditions, as detailed in the *Results* section.

Results

Self-Reported Affective State and Perceived Pain

Are subjective indices of affective empathy and empathic concern correlated with amount of autism traits?

Hypothesis IV: Pain perception (unpleasantness and intensity) will be positively correlated with amount of autism traits once alexithymia is controlled for.

Hypothesis V: Amount of autism traits will be negatively correlated with empathic concern and positively correlated with personal distress.

What other factors are associated with pain perception and empathic concern (versus personal distress)?

Hypothesis VIII: Self-regulation scores will be positively correlated with empathic concern and negatively correlated with perception of pain and personal distress. In other words, better self-regulation will be associated with higher empathic concern and lower personal distress and perceived pain intensity/unpleasantness.

Hypothesis IX: Cognitive empathy will be positively correlated with perceived pain and empathic concern.

Three control questions related to the video content were asked to test attention. Accuracy on the control questions ranged between 77% (age of hand) and 93% (object used). Six participants answered more than one of the control questions incorrectly. These participants were excluded from analyses of perceived pain and affective state ratings.

Pain perception. Table 13 shows that, on average, participants perceived the pain delivery as very intense and unpleasant (M = 5.12 and 5.18, respectively; where 7 = *extremely* and 1 = *not at all*). Intensity and unpleasantness scores were very highly correlated at each measurement time (rs = .69 - .98, all ps < .001).

Table 13

Perceived Pain and Affective State Reports by Video Condition

Condition	Pain unpleasantness		Pain intensity		Concern		Distress	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Static hand	1.45	1.33	1.45	1.32	1.40	1.00	1.30	0.89
Cotton bud	1.29	1.01	1.33	1.00	1.43	0.99	1.31	0.91
Tomato	1.40	1.16	1.48	1.29	1.39	0.98	1.37	0.90
Needle	5.18	1.68	5.12	1.67	3.53	1.79	3.54	1.80

For the mixed-effects model, pain perception responses to the pain videos were predicted from medication use, condition (where the Static Hand condition was used as the comparison group), AI, self-regulation, performance cognitive empathy, and the interaction between these variables and perception type (unpleasantness, intensity). The model was fit with a random intercept for ID, $\sigma^2_{ID} = 2.35$, $\sigma^2_{resid} = 0.11$. Non-significant interactions and variables were dropped from the final analysis, leaving medication, condition and self-regulation as significant predictors of pain perception, $R^2_M = .63$, $R^2_C = .88$ (see Table 14).

Table 14

Predictors of Pain Perception

Fixed effects	*SS*	*MS*	df_{effect}	df_{error}	*F*-value	Probability	
Medication	2.55	2.55	1	81.29	4.65	.034	*
Condition	312.29	104.10	3	83.18	189.63	< .001	***
Self-regulation	3.10	3.10	1	81.28	5.64	.020	*

Random effects										
Group	*N*	Slope	Variance	Correlation						
ID	84	(Intercept)	0.78							
		Cotton bud	0.64	- .65						
		Tomato	0.93	- .38	.47					
		Needle	2.61	- .33	.31	.17				
		Pain Intensity	0.01	- .28	.02	- .33	.42			
		Cotton bud*Pain intensity	0.01	- .02	.19	- .39	- .16	.68		
		Tomato*Pain intensity	0.14	- .55	.45	- .17	.28	.85	.77	
		Needle*Pain intensity	0.17	- .49	.32	- .09	.04	.59	.65	.65
Resid	8056		0.55							

Note. Random effects: ID (intercept), condition (slope), pain perception type (slope). Resid = residuals.

* $p < .05$, ** $p < .01$, *** $p < .001$.

In general, participants rated the pain condition videos as significantly more painful than the non-pain conditions, **β** = 3.81, *SE* = 0.17, *t* (83.09) = 22.50, $p < .001$. Those with poorer self-regulation rated the pain as more unpleasant and intense than those with good self-regulation skills, **β** = - 0.16, *SE* = 0.06, *t* (81.28) = - 2.37, $p \leq .020$. Furthermore, across all conditions, participants using medication had significantly higher scores on both pain unpleasantness and pain intensity, **β** = 0.34, *SE* = 0.16, *t* (81.29) = 2.16, $p \leq .034$. Figure 10 shows the correlations. Participants' sensitivity to empathy-inducing situations was also calculated by taking the difference scores between the average response to the pain condition and the average response to the non-pain conditions. However, no variables significantly predicted change in pain perception.

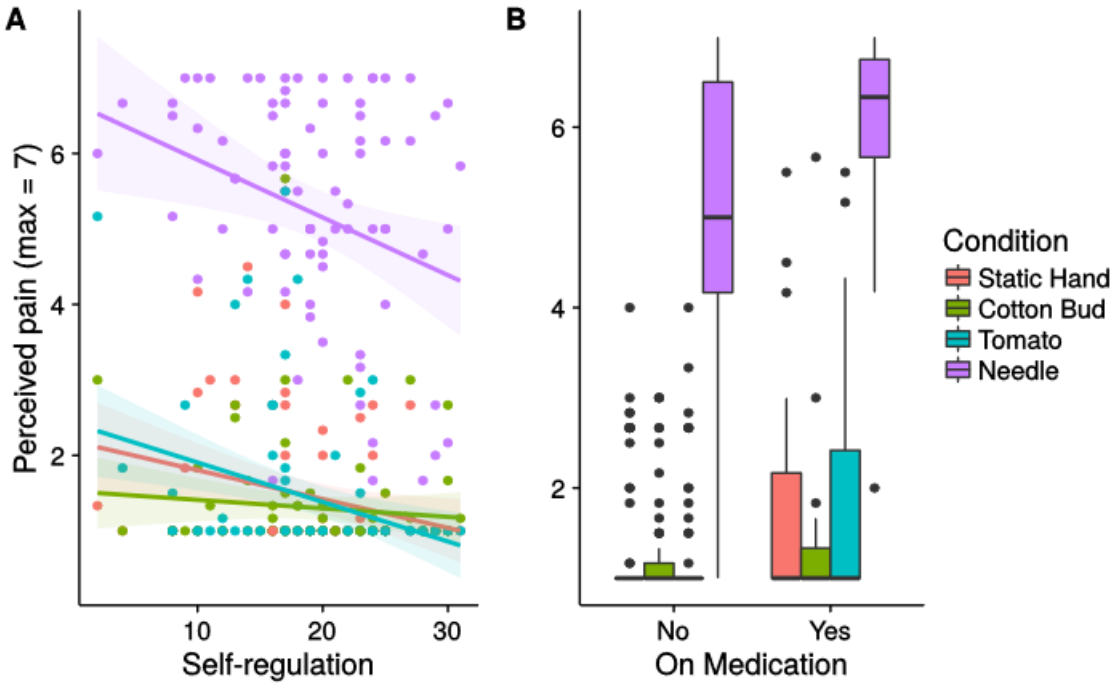

Figure 10. Self-regulation skills (A) and medication use (B) predict absolute scores of perceived pain. As there was no difference between pain intensity and unpleasantness, the responses were averaged in these plots. Shaded areas indicate the 95% confidence interval of the linear regression. The lower and upper whiskers of the box plot represent the values within 1.5 times the interquartile range.

Affective state ratings. Internal consistency for state empathic concern was very high at each of the affective state rating times (αs = .94 - .97), indicating that item ratings were nearly identical. State personal distress had similarly high internal consistency at each time point (αs = .96 - .98). Additionally, state empathic concern and personal distress were highly correlated at each time point (*r*s = .62 - .88, all *p*s < .001). On average, participants reported moderate empathic concern and personal distress during the pain condition (*M* = 3.53, *SD* = 1.79 and *M* = 3.54, *SD* = 1.80, respectively; where 1 = *not at all* and 7 = *extremely*) and no concern or distress (*M*s = 1.30 – 1.43, *SD*s = 0.90 – 1.34) during the non-pain conditions (see Table 13, p. 123).

Affective state responses were predicted from medication use; the interaction between state (concern, distress), condition and AI; the interaction between state and self-regulation; and the interaction between state and performance cognitive empathy. Non-significant interactions and variables were dropped from the final analysis, leaving condition, medication and self-regulation, $R^2_M = .42$, $R^2_C = .89$ (see Table 15). In general, participants reported significantly more empathic concern and personal distress during the pain condition videos ($\beta = 2.22$, *SE* = 0.18, *t* [83.03] < 12.55, $p \leq .001$). Medication use was associated with higher affective states, with no difference between empathic concern and personal distress ($\beta = 0.40$, *SE* = 0.17). Participants with poorer self-regulation reported increased affective responses (both empathic concern and personal distress) to all conditions ($\beta = -0.23$, *SE* = 0.07, *t* [81.03] = - 3.36, $p \leq .001$).

Table 15

Predictors of Affective Responses to Painful and Non-Painful Conditions

Fixed effects	*SS*	*MS*	df_{effect}	df_{error}	*F*-value	Probability	
Medication	1.49	1.49	1	81.03	5.90	.017	*
Condition	46.81	15.60	3	83.00	61.94	< .001	
Self-regulation	2.85	2.85	1	81.03	11.29	.001	***

Random effects

Group	*N*	Slope	Variance	Correlation					
ID	84	(Intercept)	0.50						
		Cotton bud	0.29	- .35					
		Tomato	0.42	- .41	.43				
		Needle	2.88	- .31	.42	.32			
		Distress	0.20	- .05	- .02	.10	.02		
		Cotton bud *Distress	0.02	- .02	- .10	.24	- .23	.41	
		Tomato*Distress	0.19	- .06	.06	- .29	- .19	- .14	18
		Needle*Distress	0.60	.05	- .09	- .16	- .31	.12	.62 .51
Residual	8056		0.25						

Note. Random effects: ID (intercept), condition (slope), affective state (slope).

* $p < .05$, ** $p < .01$, *** $p < .001$.

Difference scores between pain and non-pain conditions were again calculated to estimate participants' sensitivity to empathy-inducing situations. Similar to the previous analyses, empathy and personal distress difference scores were highly correlated (r = .91, p < .001). Affective state difference scores were predicted from the same fixed effects used to predict absolute affective state. The analysis had a random intercept for ID, σ^2_{ID} = 2.01, σ^2_{resid} = 0.26, and no random slope. In this model, only self-regulation significantly predicted differences in affective state, R^2_M = .08, R^2_C = .89, F (1, 82) = 8.04, $p \leq .006$. Those with poorer self-regulation reported larger differences in affective states between pain and non-pain videos (β = - 0.45, SE = 0.16; see Figure 11).

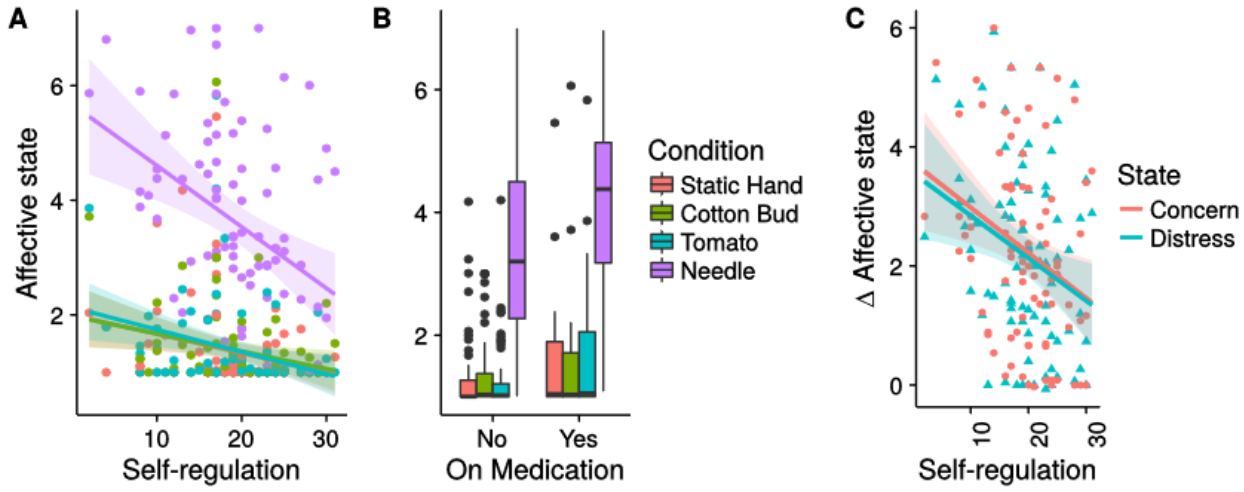

Figure 11. Self-regulation skills (A) and medication use (B) predicted absolute affective state scores. Self-regulation also predicted differences in affective state between painful and non-painful conditions (C). As there was no difference between empathic concern and personal distress, the responses were averaged in plots A and B. Shaded areas indicate the 95% confidence interval of the linear regression. The lower and upper whiskers of the box plot represent the values within 1.5 times the interquartile range.

In summary, perceived pain, empathic concern and personal distress were higher in the pain than the non-pain conditions. Contrary to the hypotheses, AI was not correlated with either pain perception (neither intensity nor unpleasantness; Hypothesis IV) or affective state (neither empathic concern nor personal distress; Hypothesis V). However, medication use was associated with higher affective state and pain perception ratings. Self-regulation scores were negatively correlated with absolute levels of empathic concern and personal distress, and with changes in affective states. Contrary to hypotheses, there was no difference in the direction of the relationships between self-regulation and empathic concern and self-regulation and personal distress. I had predicted that poor self-regulation would be associated with *lower* empathic concern and *greater* personal distress. As expected, poorer self-regulation was associated with greater absolute levels of perceived pain intensity/unpleasantness (Hypothesis VIII). Contrary to what was hypothesised, performance cognitive empathy did not predict pain perception or empathic concern (Hypothesis IX).

Muscle Reactivity

Are physiological indices of affective empathy and empathic concern correlated with amount of autism traits?

Hypothesis VI: Amount of autism traits will be positively correlated with muscle activity.

What other factors are associated with pain perception and empathic concern (versus personal distress)?

Hypothesis XI: Poorer self-regulation and cognitive empathy will be associated with increased muscle reactivity.

On average, muscle activity decreased from baseline in the non-pain conditions. In the needle condition, muscle activity first decreased and then increased in both the FDI and ADM muscle regions from the time the needle penetrated the hand (2.1 s) to the time of maximum penetration (4 s; see Figure 12). Table 16 shows the mean muscle activity relative to baseline at the 2.0 – 2.2 s and 4.0 – 4.2 s epochs.

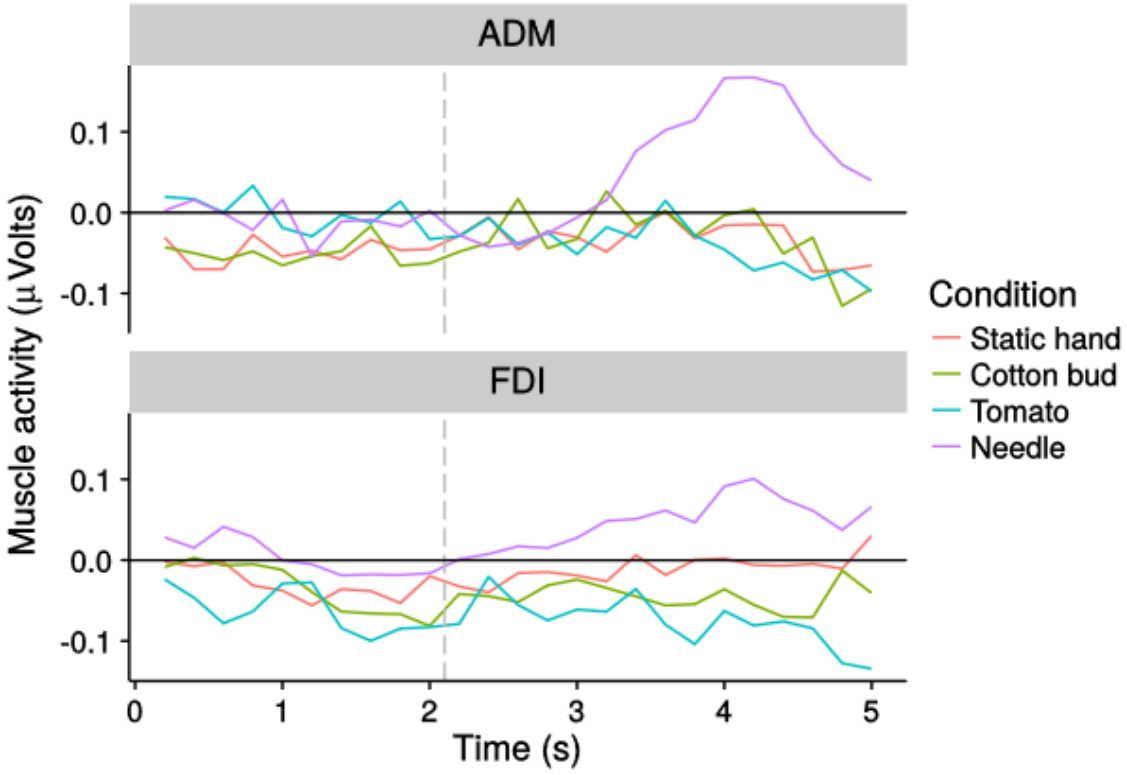

Figure 12. The average change in muscle activity from baseline in the Abductor digiti minimi (ADM) and First dorsal interosseous (FDI) muscle regions. Time 0 indicates the start of the video. The needle penetrated the hand at approximately 2.1 s.

Table 16

Average Change in Muscle Activity from Baseline (μV) During the Start (2.0 – 2.2 s) and Peak (4.0 – 4.2 s) of the Pain Epochs, and Average Muscle Slope During Pain Observation

Muscle	Time	Static hand		Cotton bud		Tomato		Needle	
		M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
ADM	Pain start	- 0.03	0.67	- 0.05	0.43	- 0.03	0.70	- 0.03	0.72
	Pain peak	- 0.01	0.94	0.00	0.77	- 0.07	0.71	0.17	1.30
	Slope	- 3.55	33.17	- 2.80	35.70	- 1.43	36.49	5.88	36.50
FDI	Pain start	- 0.03	0.44	- 0.04	0.46	- 0.08	0.82	0.00	0.66
	Pain peak	- 0.01	0.42	- 0.06	0.44	- 0.08	0.84	0.10	0.98
	Slope	0.32	32.54	0.93	35.18	- 2.27	32.02	2.60	31.75

Note. ADM = Abductor digiti minimi; FDI = First dorsal interosseous.

Average activity. To test whether the empathy induction was successful, I ran a preliminary linear mixed-effects model predicting muscle activity from time (3 levels: video start, pain start, pain peak), muscle, and condition[9]. The analysis showed a significant interaction between time and condition, F (6,1440) = 3.28, $p \leq .003$, but no other significant interactions. As I was interested in whether muscle activity was greater during the pain condition than the non-pain conditions at the time of the most intense pain, but not at the start of the video, I conducted two dependent *t*-tests comparing the experimental conditions (pain vs. 'no pain', with 'no pain' conditions aggregated) at 200 ms and 4.2 s. There was no significant difference in muscle activity between conditions at 200 ms, M_D = 0.03, t (90) =

[9] This analysis is essentially equivalent to a three-way repeated-measures ANOVA with muscle, time and condition as the independent variables.

1.24, $p \leq .101$, $d = 0.12$. In contrast, at 4.2 s, muscle activity was significantly greater in the pain condition than the non-pain condition, $M_D = 0.17$, t (90) = 2.52, $p \leq .006$, $d = .24$.

To test the hypotheses that AI, as well as self-regulation and cognitive empathy, predict muscle mimicry, I predicted muscle activation in the 200 ms after the period of greatest pain in the videos, time 4.0 – 4.2 s. This was an a priori time window, based on the time in the videos where the inflicted pain was the greatest (i.e., the needle had fully penetrated the hand). Video block (one, two, or three) was used as a fixed effect to test whether muscle activity habituated over the course of the experiment, and alexithymia was used as a control variable. As a maximal model did not converge, a nested random-effects model was used. Muscle activity was higher in the pain than the non-pain conditions in both the ADM and FDI muscles (see Table 17 and Figure 13). However, no other variables significantly predicted muscle activity.

Table 17

Correlation Coefficients for Muscle Activity at 4.0 – 4.2 s (Relative to Baseline)

Fixed effects	**β**	*SE*	*df*	*t*-value	Probability	
Cotton bud	0.01	0.06	547.98	0.13	.898	
Tomato	- 0.04	0.06	549.20	-0.63	.526	
Needle	0.16	0.06	547.98	2.65	.008	**

Random effects		
Group	*N*	Variance
Condition in muscle in ID	736	0.11
Muscle in ID	184	0.08
ID	92	0.11
Residual	2206	0.78

Note. R^2_M = .01, R^2_C = .18. FDI = First dorsal interosseous.

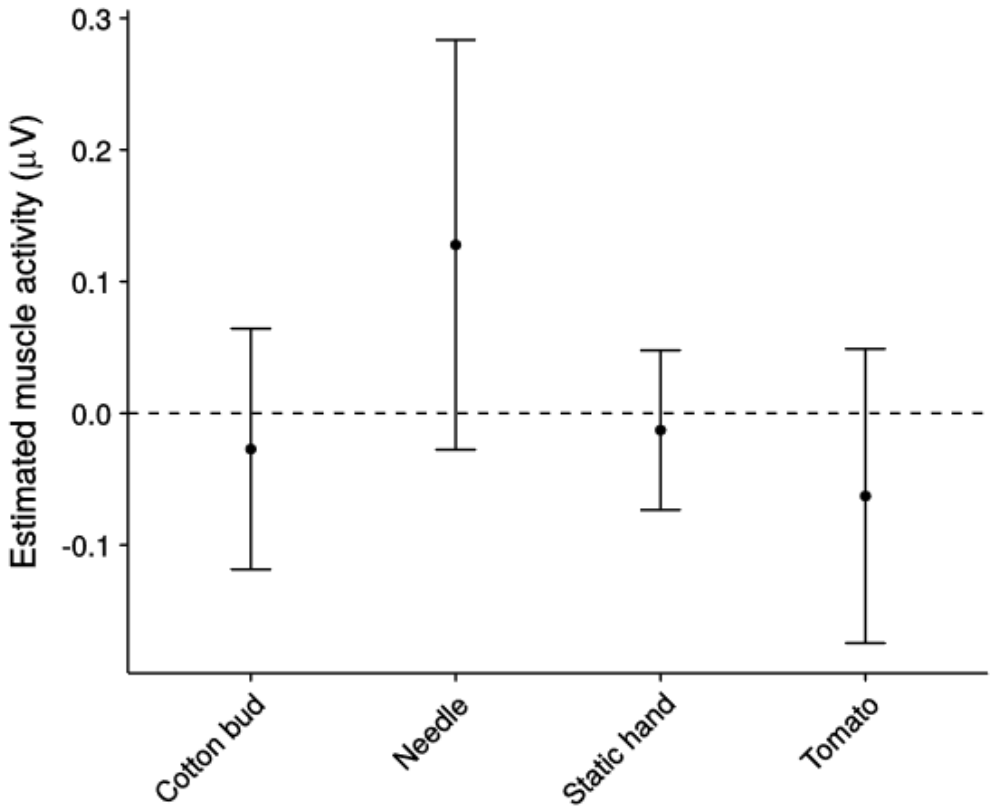

Figure 13. Average muscle activity at 4.0 – 4.2 s (compared to baseline) to observing painful and non-painful stimulation of a target hand. Participants showed greater activity in both muscles to the needle condition. Error bars show 1 *SD* above and below the mean; with *SD*s corrected for repeated measures.

Slope. Using the slope of muscle activity during the videos, condition predicted a significant but small change in muscle activity over time, F (3, 341.85) = 4.26, $p \leq .006$. Participants experienced increased change in activity over time in both muscles when observing the pain condition compared with the non-pain conditions. Medication use, type of muscle, AI scores, empathy and alexithymia were not correlated with change in activation over time. Table 18 and Figure 14 shows the relationships between condition and muscle slope.

Table 18

Linear Mixed-Effects Model Predicting Change in Muscle Activity over Time (Muscle Slope) to Painful and Non-Painful Conditions

Fixed effects	**β**	*SE*	*df*	*t*-value	Probability	
Cotton bud	1.04	2.08	270.58	0.50	.617	
Tomato	- 0.13	2.05	370.37	- 0.06	.950	
Needle	6.31	2.13	257.70	2.96	.003	**

Random effects										
Group	*N*	Slope	Variance	Correlation						
ID	91	(Intercept)	22.63							
		FDI	119.00	- .69						
		Cotton bud	141.02	- .08	- .17					
		Tomato	77.00	.28	.45	- .06				
		Needle	165.76	.57	- .69	.61	.05			
		FDI*Cotton bud	114.83	.16	.14	- .98	.09	- .64		
		FDI*Tomato	267.20	- .01	- .66	.62	- .78	.49	- .61	
		FDI*Needle	139.88	- .78	.51	.03	- .43	- .73	.02	.13
Residuals	2182		1066.46							

Note. Random effects: ID (intercept), muscle (slope), condition (slope). R^2_M = .01, R^2_C = .10.

AI = Autism Index; FDI = First dorsal interosseous.

* $p < .05$, ** $p < .01$, *** $p < .001$.

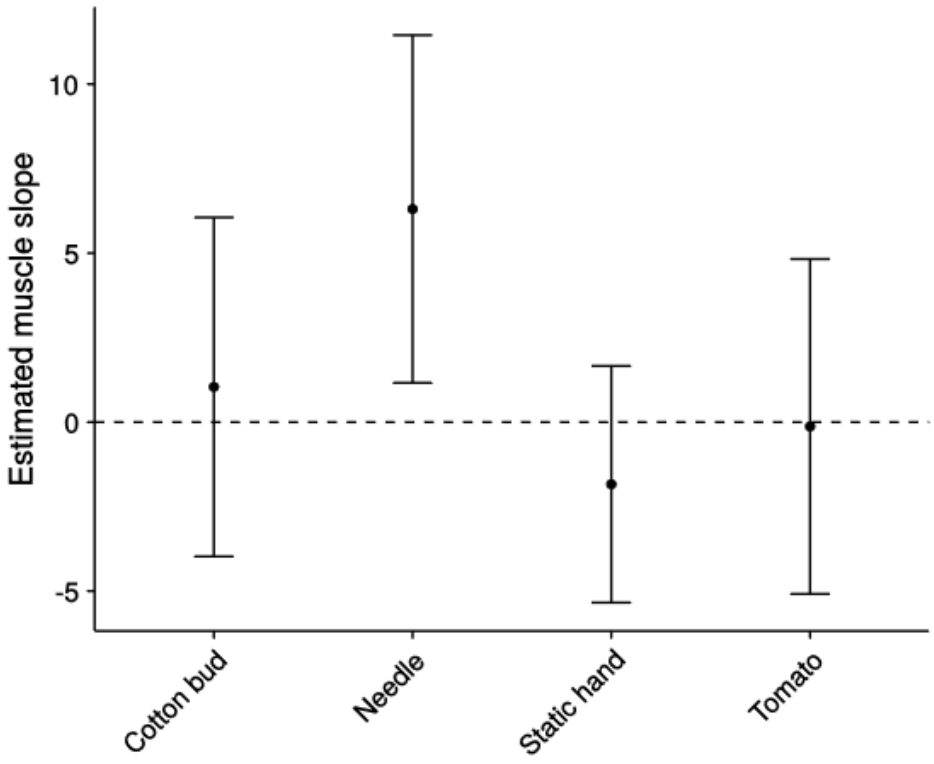

Figure 14. Muscle slope to observing painful and non-painful stimulation of a target hand. In the needle condition, participants showed increases in activity over time in both muscles. Error bars show 1 *SD* above and below the mean; with *SD*s corrected for repeated measures.

In summary, muscle amplitude and slope were greater in the pain condition than the non-pain conditions. Contrary to expectations, AI scores were not significantly correlated with muscle activity (Hypothesis VI). Affective states during the conditions and trait empathy facets were not significantly correlated with muscle activity either (Hypothesis XI).

Resting State Autonomic Arousal, Empathy and Autism

Is there evidence of resting state autonomic dysregulation in ASD? Is resting state autonomic activity associated with empathy?

Hypothesis III: Higher resting state parasympathetic arousal (vagal cardiac control) will be associated with higher trait affective empathy and self-regulation scores.

Hypothesis X: Higher resting state parasympathetic arousal (vagal cardiac control) will be associated with increased state empathic concern, whereas higher resting state sympathetic arousal will be associated with increased personal distress.

Resting state autonomic arousal indices are presented in Table 19. Pre-ejection period and SCL at rest (baseline) were not correlated, r (73) = .07, $p \leq .523$, so these scores were kept separate and not aggregated to a single sympathetic arousal variable. Baseline RSA values had a wide range, M = 82.59 ms, SD = 41.63 ms, 95% CI [26.75, 173.82]. As a reminder, RSA was not collected during the experimental conditions as the stimulus duration was not long enough to measure RSA.

Table 19

Autonomic Arousal to Painful and Non-Painful Conditions

Condition	HR (bpm)		PEP (ms)		SCL (μS)	
	M	*SD*	*M*	*SD*	*M*	*SD*
Baseline	72.19	11.93	115.53	17.80	4.12	2.17
Static hand	71.01	12.48	117.66	20.06	4.34	2.16
Cotton bud	70.60	12.82	117.43	20.13	4.35	2.15
Tomato	71.09	13.13	117.26	20.00	4.33	2.11
Needle	70.67	12.62	117.10	20.12	4.39	2.22

Note. HR = heart rate; bpm = beats per minute; PEP = pre-ejection period; SCL = skin conductance level.

Correlations between the resting state measures are given in Table 20. The between-subject correlation between RSA and respiration rate was significant, r (89) = - .32, p < .001. Thus, I predicted RSA from participants' resting state respiration rate (M = 15.41 breaths per minute (bpm), SD = 2.51, 95% CI [10.14, 20.47]) and tidal volume (M = 86.05 mΩ/s, SD = 45.91, 95% CI [27.40, 217.02]), and used the residuals of that analysis as an indicator of cardiac vagal control (M = -1.03, SD = 41.15, 95% CI [-50.23, 80.41]).

Table 20

Correlations Between Resting State Autonomic Arousal and Empathy Measures

	1	2	3	4	5	6	7	8	9	10	11	12	13
1. HR													
2. PEP	- .19												
3. RSA	- .50***	- .05											
4. RR	.09	.00	- .32**										
5. TV	.10	- .27*	.11	- .22*									
6. VC	- .50***	- .04	.95***	.00	.00								
7. SCL	.21*	.02	.04	.04	- .11	.06							
8. AI	.32**	- .09	- .16	.12	- .03	- .12	.11						
9. AE	.25*	- .11	- .21	.03	.08	- .21	.15	- .15					
10. TCE	- .02	.14	- .04	- .06	.01	- .06	.02	- .55***	.57***				
11. PCE	.10	.07	- .09	- .15	- .10	- .14	- .08	- .3**	.07	.17			
12. SR	- .25*	- .03	.15	- .08	.04	.13	- .30**	- .40***	- .45***	.08	.17		
13. Concern	.02	.13	- .25	.07	- .11	- .24*	.01	- .01	.23*	.03	- .06	- .30**	
14. Distress	- .01	.12	- .24	.09	- .12	- .22*	.02	.01	.19	- .04	- .01	- .33**	.91***

Note. HR = heart rate; PEP = pre-ejection period; RSA = respiratory sinus arrhythmia; RR = respiration rate; TV = tidal volume; VC = vagal cardiac control; SCL = skin conductance level; AI = Autism Index; AE = affective empathy; TCE = trait cognitive empathy; PCE = performance cognitive empathy; SR = self-regulation; Concern = change in empathic concern; Distress = change in personal distress.

* $p < .05$, ** $p < .01$, *** $p < .001$.

To test the hypotheses that resting state arousal is associated with autism traits and with empathy, resting state arousal variables were used to predict AI scores, trait affective empathy, trait and performance cognitive empathy, and trait self-regulation in separate linear regressions. Affective state difference scores (i.e., the difference in affective state rating between painful and nonpainful conditions) were also predicted from resting state arousal in a random-effects model with participant ID as the random intercept.

Resting state heart rate was positively correlated with AI scores, $\beta = 0.57$, $SE = 0.21$, $t\ (75) = 2.80$, $p \leq .005$. However, when participants on antidepressants ($n = 5$) – which have been associated with higher resting heart rate (Mathewson et al., 2011) - were excluded, heart rate was no longer positively correlated with AI, $\beta = 0.41$, $SE = 0.21$, $t\ (70) = 1.96$, $p \leq .054$ (see Figure 15). This may have been the result of reduced power in the smaller sample, as the coefficient estimates were similar; however, in both models (with and without antidepressants), the overall effects sizes were small ($R^2_{adj} = .09$ and $R^2_{adj} = .04$, respectively). Resting state vagal cardiac control, resting state pre-ejection period, and their interaction did not predict AI scores in either model (see Table 21). Overall, the model without participants on antidepressants was not significant, $F\ [4, 70] = 1.75$, $p \leq .149$. The residuals were moderately positively skewed in both models. Adding variance structures to the models or transforming the variables did not improve model fit. The general conclusion is that autonomic arousal variables were not good predictors of AI.

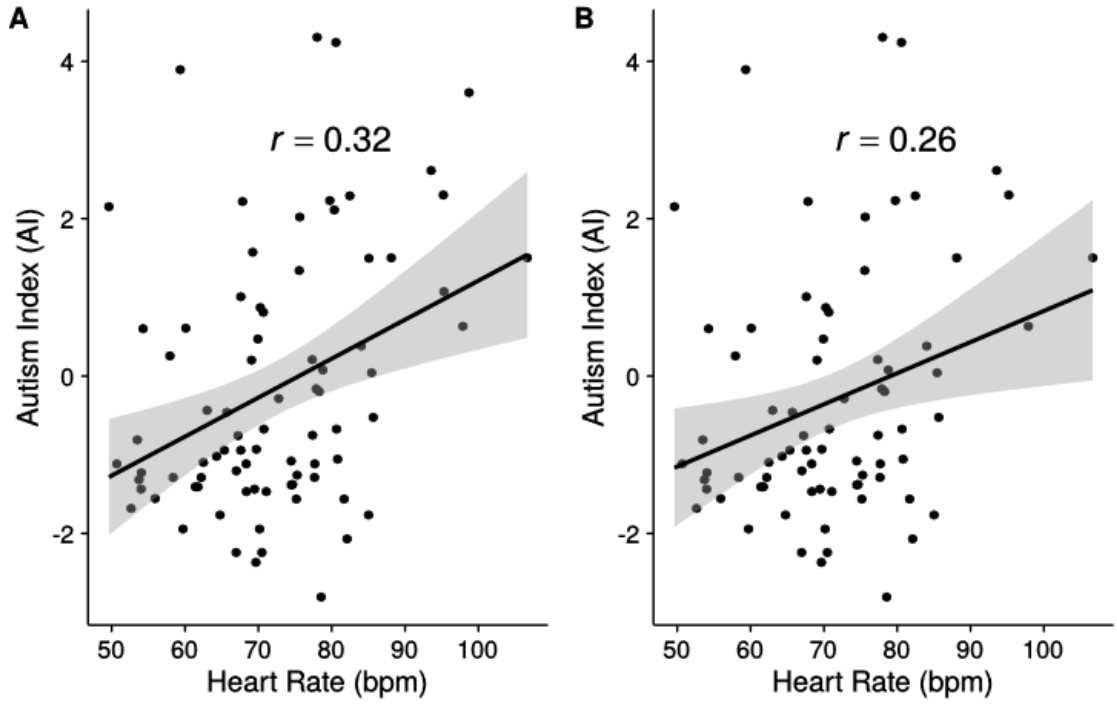

Figure 15. The correlation between heart rate and AI scores, with (A) and without antidepressants (B). Shaded areas indicate the 95% confidence interval of the model predictions.

Table 21

Linear Regression Results of Resting State Autonomic Arousal and Autism and Empathy Traits

Fixed effects	β	*SE*	df_{error}	*SS*	*MS*	*F*-value	Probability	
AI[a]								
Vagal control	- 0.05	0.21		7.16	7.16	2.93	.091	
PEP	0.11	0.23		0.51	0.51	0.21	.651	
HR	0.57	0.21		19.95	19.95	8.15	.006	**
Vagal control * PEP	0.21	0.26		1.56	1.56	0.64	.427	
Residuals			75	183.67	2.45			
Affective empathy (T)								
Vagal control	- 1.02	2.01		512.37	512.37	2.30	.134	
PEP	- 1.89	2.20		299.57	299.57	1.34	.250	
HR	2.83	1.97		456.39	456.39	2.05	.157	
Vagal control * PEP	- 0.51	2.48		9.32	9.32	0.04	.839	
Residuals			74	16492.71	222.87			
Affective state[b]								
State[c]	- 0.12	0.08	72	0.55	0.55	2.25	.138	
Vagal control	- 0.29	0.22	71	0.65	0.65	2.66	.107	
PEP	- 0.27	0.24	71	0.08	0.08	0.35	.558	
HR	- 0.25	0.21	71	0.32	0.32	1.33	.254	
State* Vagal control	- 0.14	0.09	72	0.63	0.63	2.56	.114	
State* PEP	0.26	0.11	72	1.43	1.43	5.84	.018	*
Vagal control * PEP	- 0.40	0.27	71	0.14	0.14	0.57	.453	
State* Vagal control *PEP	0.40	0.12	72	2.70	2.70	11.04	.001	**

continued overleaf

Table 21 (cont.)

Cognitive Empathy (T)								
Vagal control	- 0.44	0.68		1.13	1.13	0.04	.833	
PEP	0.69	0.74		9.48	9.48	0.37	.543	
HR	- 0.39	0.66		6.88	6.88	0.27	.604	
Vagal control * PEP	0.81	0.84		24.04	24.04	0.95	.333	
Residuals			74	1873.56	25.32			
Cognitive Empathy (P)								
Vagal control	0.05	0.12		0.01	0.01	0.02	0.895	
PEP	- 0.07	0.13		0.07	0.07	0.09	0.764	
HR	0.03	0.12		0.06	0.06	0.07	0.788	
Vagal control * PEP	- 0.09	0.16		0.28	0.28	0.36	0.550	
Residuals			70	54.65	0.78			
Self-regulation[a]								
Vagal control	0.05	0.77		57.32	57.32	1.74	.191	
PEP	- 0.23	0.85		0.00	0.00	0.00	.999	
HR	- 1.66	0.76		158.26	158.26	4.81	.031	*
Vagal control *PEP	0.14	0.95		0.76	0.76	0.02	.880	
Residuals			74	2434.88	32.90			

Note. All models: $df_{effect} = 1$. AI = Autism Index; PEP = pre-ejection period; HR = heart rate; T = trait; P = performance.

[a] Model uncorrected for antidepressant use. [b] Mixed-effects model; number of observations = 152, number of groups (ID) = 74. Coefficient estimates are provided for the fixed effects. The model was fit with a random intercept for participant ID, $\sigma^2_{ID} = 2.22$, $\sigma^2_{resid} = 0.24$.

[c] Concern versus personal distress (baseline).

* $p < .05$, ** $p < .01$, *** $p < .001$.

Pre-ejection period and cardiac vagal control did not predict affective state difference scores on their own. However, the interaction between state type (empathic concern versus personal distress), cardiac vagal control and pre-ejection period significantly predicted the amount of difference in affective responses between the pain and non-pain conditions. From Figure 16, p. 146, the biggest difference seems to be in participants with long pre-ejection periods (low sympathetic arousal): Participants with low sympathetic arousal and low parasympathetic arousal (low vagal cardiac control) at rest had greater changes in affective state than participants with low sympathetic arousal and high parasympathetic arousal, $\boldsymbol{\beta}$ = 0.40, SE = 0.12, t (72) = 3.32, $p \leq .001$. This effect remained when participants on antidepressants were excluded. To examine the interaction further, participants with higher than average pre-ejection period (i.e., low sympathetic arousal) and lower than average cardiac vagal control were compared with participants with higher than average pre-ejection period (i.e., low sympathetic arousal) and higher than average cardiac vagal control (i.e., high parasympathetic arousal) on empathic concern and personal distress. These groups are referred to as the 'co-inhibition' (n = 24) and 'predominantly parasympathetic' (n = 17) groups, respectively. Both groups had low sympathetic arousal, but differed on parasympathetic arousal, with the 'predominantly parasympathetic' group having greater parasympathetic arousal than the 'co-inhibition' group. These specific groups were selected for comparison, as they showed the greatest differences in Figure 16. As difference scores were not normally distributed, the groups were compared using Wilcoxon signed-rank tests. The predominantly parasympathetic group had significantly smaller changes in personal distress to the pain videos than the co-inhibition group (W = - 284, $p \leq .016$); however, there were no differences in magnitude of change in empathic concern between the groups (W = - 263.5, $p \leq .065$). It should be noted, however, that the fixed effects only explained a small proportion of the variance, R^2_M = .06, R^2_C = .90. As can be seen from the conditional effect

size (R^2_C), the majority of the variance was explained by inter-individual differences (i.e., participant ID). The predominantly parasympathetic and co-inhibition groups also had small and uneven sample sizes.

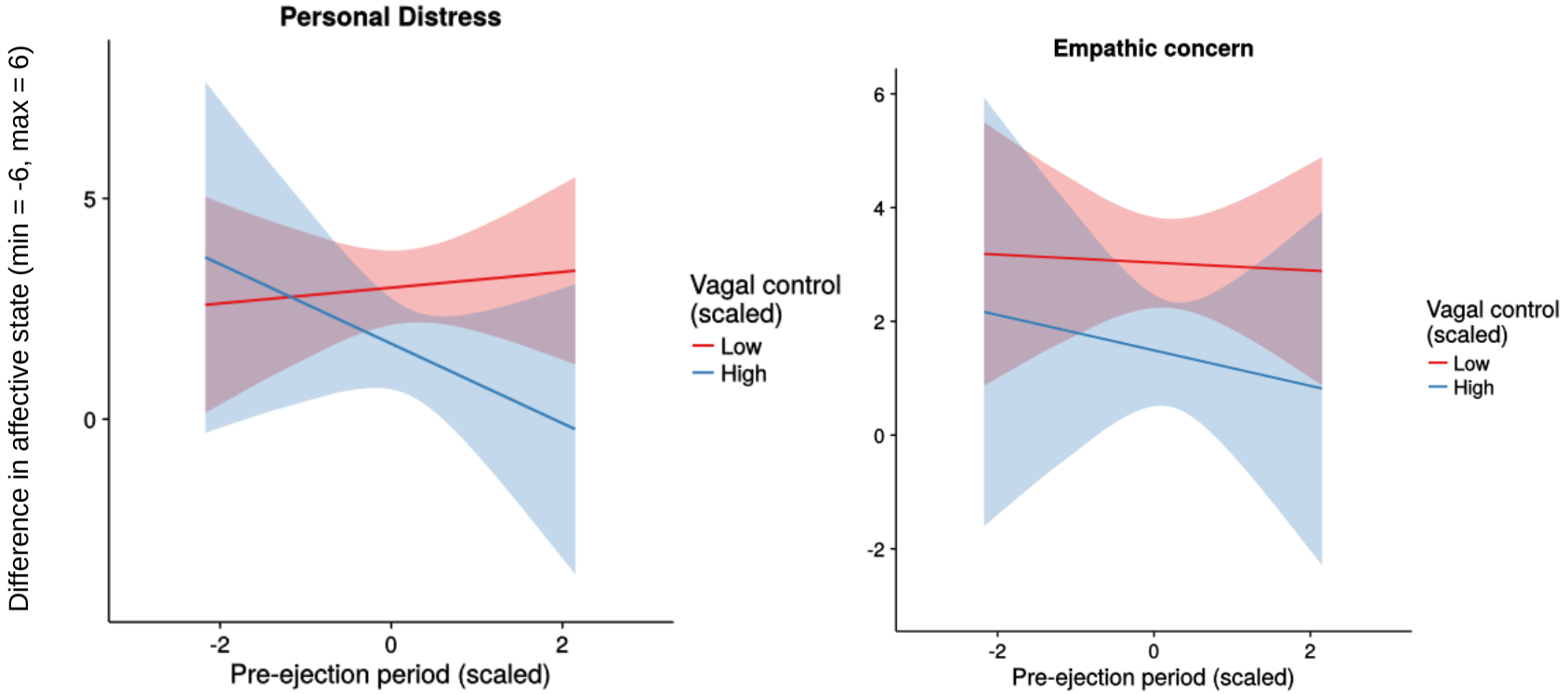

Figure 16. The interaction between cardiac vagal control and pre-ejection period (PEP) on change in affective state ratings. Low and high levels of cardiac vagal control represent 1 *SD* below and above the mean vagal cardiac control. High pre-ejection periods indicate low sympathetic arousal. Shaded areas indicate the 95% prediction intervals of the random-effects models.

In a series of linear regressions, the autonomic variables did not significantly predict trait affective empathy (R^2_{adj} = .02, F [4, 74] = 1.43, $p \leq .235$), or trait or performance cognitive empathy (R^2_{adj} = 0, F [4, 74] = 0.41, $p \leq .800$, and R^2_{adj} = 0, F [4, 70] = 0.41, $p \leq .969$, respectively). Neither did autonomic arousal predict self-regulation (R^2_{adj} = .03, F [4, 73] = 1.69, $p \leq .162$). Again, resting state heart rate was significantly negatively correlated with self-regulation scores in the overall sample, β = - 1.66, SE = 0.76, t (74) = - 2.20, $p \leq .031$, but did not significantly predict self-regulation in participants who were not on antidepressants, β = - 1.25, SE = 1.13, t (69) = - 1.61, $p \leq .113$. Resting state pre-ejection period, vagal cardiac control, and their interaction did not significantly predict self-regulation. Three potentially influential values were identified, but these cases were not removed as their removal did not change the interpretation of the model. Results from the analyses are displayed in Table 21, p. 142.

In summary, AI scores were not correlated with pre-ejection period or cardiac vagal control at rest. Though baseline heart rate had a small but significant positive correlation with AI scores, this correlation was no longer significant when participants with antidepressants were excluded. Furthermore, resting state autonomic arousal was not significantly associated with trait affective empathy (Hypothesis III). Increased heart rate at rest, but not pre-ejection period or vagal cardiac control, significantly predicted poorer self-regulation skills; however, this correlation was also not significant when participants on antidepressants were excluded[10]. Hypothesis X was partially upheld: As expected, the combination of high resting state parasympathetic arousal) and low sympathetic arousal (i.e., predominantly parasympathetic arousal) was associated with significantly smaller changes in personal distress relative to autonomic co-inhibition at rest. In contrast, changes in empathic concern

[10] Similarly, medication significantly predicted heart rate, F (1,78) = 8.43, R^2 = .09, p = .005, but did not significantly predict pre-ejection period, F (1,78) = 1.23, R^2 = .002, p = .270, or cardiac vagal control, F (1,81) = 1.41, R^2 = .004, p = .238.

did not differ between the predominantly parasympathetic (high resting state parasympathetic arousal and low sympathetic arousal) and co-inhibition (low resting state parasympathetic arousal and low sympathetic arousal) groups.

Autonomic Responses to Stimuli

Are physiological indices of affective empathy and empathic concern correlated with amount of autism traits?

Hypothesis VII: Amount of autism traits will be positively correlated with sympathetic reactivity.

What other factors are associated with pain perception and empathic concern (versus personal distress)?

Hypothesis XII: Increased empathic concern and better self-regulation will be associated with increased parasympathetic reactivity and potentially increased sympathetic reactivity (autonomic co-activation).

Preliminary random-effects models with condition as the only predictor were run to test whether physiological arousal during the videos differed significantly from baseline. The effect of condition was significant for pre-ejection period, F (4, 316) = 6.71, $p < .001$, heart rate, F (4, 316) = 7.64, $p < .001$, and SCL, F (4,376) = 5.60, $p < .001$. RSA was not tested as it was not recorded during the videos. Tukey's post hoc tests showed that SCLs were significantly higher in the needle condition than baseline and any of the non-pain conditions (all ps < .001). In contrast, heart rate reduced and pre-ejection period increased significantly for all the videos compared to baseline conditions (all ps < .001), but was not significantly different between the pain and non-pain conditions (ps > .05). This did not change when interactions between AI and heart rate/pre-ejection period or block and heart rate/pre-ejection

period were added to the models. Refer back to Table 19, p. 138, for the descriptive statistics of the autonomic variables.

To test Hypotheses VII and XII, physiological arousal was predicted from medication use, condition, AI, empathic concern and self-regulation. To test for different habituation rates, the interactions between condition, AI and block were also added to the models. Three different linear mixed-effects models were run predicting pre-ejection period, SCL and heart rate (see Table 22). In each case, arousal at resting state and block significantly predicted arousal during the video conditions. Later blocks were associated with significantly longer pre-ejection periods and lower SCL, but also increased heart rate. However, there were no interactions between block and AI in pre-ejection period, SCL or heart rate. SCL was the only physiological indicator which had significant predictors other than resting state arousal level and block. There was a significant interaction between condition and resting state SCL: SCL was significantly greater after the pain condition than the static hand condition in participants who had higher resting state SCLs ($\boldsymbol{\beta} = 0.04$, $SE = 0.02$, $t\,[446] = 2.08$, $p \leq .038$). Figure 17 shows the interaction effect. There was also a significant interaction between resting state SCL and block, with skin conductance being greater during the first stimulus block in participants who had high resting state SCLs. There were no other significant predictors of the pre-ejection period, SCL or heart rate.

Table 22

Linear Mixed-Effects Model of Autonomic Arousal to Painful and Non-Painful Conditions

Fixed effects	β	*SE*	*SS*	*MS*	*df*	*F*-value	Probability	
PEP								
Base PEP	18.26	0.54	47363.37	47363.37	1, 78.09	1133.17	< .001	***
Block	0.57	0.17	470.73	470.73	1, 87.06	11.26	.001	**
SCL								
Base SCL	2.05	0.04	70.02	70.02	1, 96.17	1461.51	< .001	***
Cotton bud	0.01	0.02	0.26	0.09	3, 362.52	1.81	.145	
Tomato	0.00	0.02						
Needle	0.04	0.02						
Block	- 0.06	0.02	0.33	0.33	1, 88.23	6.86	.010	*
Base SCL * Cotton bud	0.01	0.02	0.53	0.18	3, 362.52	3.66	.013	*
Base SCL * Tomato	- 0.03	0.02						
Base SCL * Needle	0.04	0.02						
Base SCL * Block	- 0.05	0.02	0.25	0.25	1, 88.23	5.23	.025	*
HR								
Base HR	10.68	0.31	31543.42	31543.42	1, 89.77	1153.55	< .001	***
Block	1.13	0.16	1307.42	1307.42	1, 93.57	47.81	< .001	***

continued overleaf

Table 22 (cont.)

	Random effects			Correlation						
	Group	Slope	Variance							
PEP	ID	(Intercept)	27.85							
		Block	3.72	- .43						
		Cotton bud	5.83	- .50	.71					
		Tomato	9.32	- .24	.47	.91				
		Needle	4.15	- .34	.06	.74	.81			
		Block * Cotton bud	1.58	.52	- .95	- .77	- .59	- .17		
		Block * Tomato	1.26	.25	- .69	- .96	- .94	- .70	.73	
		Block * Needle	0.48	.45	- .14	- .69	- .61	- .90	.14	.60
	Resid		41.80							
SCL	ID	(Intercept)	0.48							
		Block	0.05	- .91						
		Cotton bud	0.07	- .79	.95					
		Tomato	0.06	.97	- .82	- .74				
		Needle	0.08	- .83	.66	.67	- .94			
		Block * Cotton bud	0.01	.87	- .98	- .89	.74	- .53		
		Block * Tomato	0.01	.80	- .96	-1.00	.75	- .66	.90	
		Block * Needle	0.01	- .98	.85	.78	- 1.00	.93	- .78	- .78
	Resid		0.05							
HR	ID	(Intercept)	37.10							
		Block	3.45	- .90						
		Cotton bud	0.92	- .58	.32					
		Tomato	4.71	- .21	.44	.38				
		Needle	1.13	- .94	.79	.82	.37			
		Block * Cotton bud	0.38	.63	- .47	- .97	- .59	- .86		
		Block * Tomato	2.55	.23	- .43	- .45	-1.00	- .41	.65	
		Block * Needle	0.60	.49	- .41	- .89	- .75	- .74	.97	.80
	Resid		27.34							

Note. Random effects: ID (intercept), block (slope), condition (slope). PEP: Number of observations: 2863, number of groups: 80, R^2_M = .83, R^2_C = .89; SCL: Number of observations: 1032, number of groups: 86, R^2_M = .94, R^2_C = .99; HR: Number of observations: 3275, number of groups: 91, R^2_M = .74, R^2_C = .82.

HR = heart rate; PEP = pre-ejection period; SCL = skin conductance level.

* $p < .05$, ** $p < .01$, *** $p < .001$

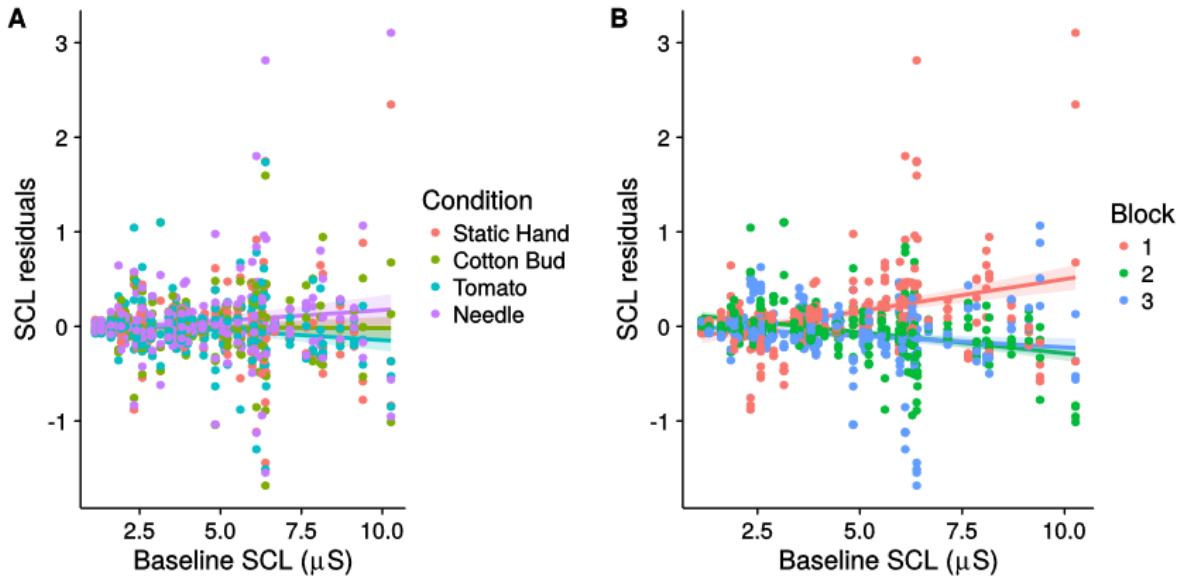

Figure 17. Skin conductance levels (SCLs) to the different conditions (A). To better see the interaction between resting state SCL and condition, SCL during pain perception was predicting from resting state SCL, and the residuals of that analysis (corresponding to changes from resting state) are depicted in the plots. Skin conductance changes were significantly greater in the needle condition compared to the non-pain condition in participants who had higher resting state SCLs. Skin conductance showed the biggest change from baseline during the first stimulus block (B). Shaded areas indicate 95% confidence intervals around the prediction.

In summary, the hypothesis that sympathetic arousal would be heightened during observation of the painful conditions was only partially upheld: SCL increased from non-pain to pain conditions in participants with higher resting state arousal, but the pre-ejection period did not. AI scores were not correlated with sympathetic arousal to the stimuli (Hypothesis VII). Empathic concern and self-regulation ratings were not significantly correlated with autonomic arousal while observing the pain (Hypothesis XII).

Discussion

This study investigated muscle and autonomic reactivity to observing another's sensory pain. To test the global empathy deficit and empathy imbalance theories, the study investigated whether autism traits were correlated with subjective empathic concern and personal distress, muscle reactivity, and sympathetic and parasympathetic autonomic arousal. The analyses controlled for cognitive empathy, self-regulation and alexithymia, which have been correlated with empathic concern and perceived pain in previous studies (Bird et al., 2010; Mailhot, Vachon-Presseau, Jackson, & Rainville, 2012; Moriguchi et al., 2007; Vachon-Presseau et al., 2011).

With regards to predictions of the neurovisceral integration and polyvagal theories, I investigated the correlation between resting state autonomic arousal (both sympathetic and parasympathetic) and subjective trait empathy and state empathic concern for sensory pain. In particular, I hypothesised that there would be a correlation between resting state autonomic arousal and trait self-regulation, so that high parasympathetic arousal and low sympathetic arousal at rest would predict better self-regulation, and in turn, lower personal distress and sympathetic reactivity to observed sensory pain. Lastly, I tested the predictions from the polyvagal theory (Porges, 2005; Porges et al., 2013) that resting state autonomic arousal would be correlated with autism traits, and that this proposed atypical arousal could explain problems with self-regulation and empathic concern (if such problems were found) in ASD. I will first discuss the results of the self-reported pain perception and affective state analyses, then turn to the results on muscle mimicry, and lastly I will discuss the autonomic arousal findings.

Self-Reported State Empathic Concern and Distress

Participants rated the pain condition videos as significantly more painful than the non-pain conditions, and reported feeling more empathic concern and personal distress during these videos. These ratings suggest that the videos were effective in eliciting empathic concern and distress in the participants. However, the empathic concern and personal distress responses were highly correlated at each measurement time. The current questions do not seem to adequately distinguish between the two concepts of empathic concern and personal distress. This result corresponds with earlier investigations into these scales' properties that found that participants reported similar levels of empathic concern and personal distress to empathy-inducing videos (Batson et al., 1991, 1997). Indeed, although Batson and colleagues argued that empathic concern and personal distress are separate constructs, a principal components analysis of the 14 emotion state adjectives used in their studies (and in this one) indicated that a single factor solution best portrays the different affective state responses (Batson et al., 1991, 1997). Batson and colleagues argue that participants report other-oriented distress along with self-oriented distress, and thus that the personal distress items are partially assessing empathic concern. In their study, participants were explicitly asked whether they felt distress for the other person or for themselves. When specifically asked to distinguish between other-oriented distress and self-oriented distress, participants predominantly reported experiencing other-oriented distress. Thus, personal distress may not have been adequately captured by the affective state questions. However, there was some indication that the affective state change scores differentiated between empathic concern and personal distress, as concern and distress were differentially predicted by resting state autonomic arousal, as is discussed later in this chapter.

Amount of autism traits was not correlated with either state empathic concern or distress[11]. These results concur with trait empathy results from Study 1 and with two previous studies that found no differences in subjective empathy for pain between ASD and neurotypical participants when participants were focused on the stimuli (de Coster et al., n.d.; Y.-T. Fan et al., 2014). Analogously, three more studies found no differences in brain activation or physiological arousal between ASD and neurotypical participants (Hadjikhani et al., 2014; Krach et al., 2015) or ASD and alexithymic participants (Bird et al., 2010) when viewing others' physical pain. Thus, in contrast to predictions of global empathy deficits (e.g., C. Gillberg, 1992, 1996), pain perception and empathic concern seem to be at least intact in individuals with high amounts of autism traits.

Use of medication was correlated with both affective state and perceived pain in the current study. Participants using medication reported greater affective reactions and higher ratings of pain unpleasantness and intensity. As discussed in Study 1, since nearly all participants on medication (77%) had high amounts of autism traits, medication use could be acting as a proxy for autism. A recent study found that individuals with ASD experience a target's pain as more unpleasant than neurotypical individuals do, and that individuals with ASD show decreased ability to discriminate between painful and non-painful conditions (Gu et al., 2015). If medication is an indicator of high ASD traits, this study corroborates their findings that individuals with high amounts of autism traits show greater affective reactions. Furthermore, though it was expected that distress scores would be positively correlated with autism traits because of poor self-regulation in this group (see, e.g., Gu et al., 2015), the non-significant results may be explained by the fact that the affective state questions did not adequately assess personal distress.

[11] Because of the similarity between the empathic concern and personal distress responses, these states will be collectively referred to as 'affective state' responses.

It is also possible that medication use has direct effects on affective states and perceived pain. Medication use, particularly antidepressant use, was associated with higher resting state heart rate in the current study, as is discussed in more detail in the *Autonomic arousal* section (this chapter) and in the *Limitations* section in Chapter 8, p. 245. Psychotropic medications have been associated with lowered heart rate variability (Alvares, Quintana, Hickie, & Guastella, 2016; Kemp et al., 2014; Licht, de Geus, van Dyck, & Penninx, 2010) and increased sympathetic activity at rest, independent of type of psychiatric disorder. It is thus conceivable that the effects of medication on resting state autonomic arousal primes the individual for heightened general subjective arousal.

In this study, neither autism traits nor medication use predicted change in affective state or pain scores, implying that participants on medication tended to give higher ratings overall, rather than having heightened reaction only to the pain conditions. These findings may indicate that participants on medication - and if medication is a proxy for autism, potentially also participants with high amounts of autism traits - do not have a greater distress response to empathy stimuli in particular, but rather show heightened general reactivity. These results correspond to physiological studies which have found heightened general activity in ASD (Ming, Julu, Brimacombe, Connor, & Daniels, 2005).

Cognitive empathy skills were not associated with pain perception or empathic concern. Likewise, alexithymia was not correlated with perceived pain ratings in this study, or in previous studies of participants with alexithymia (Silani et al., 2008) or comorbid ASD and alexithymia (Bird et al., 2010). Though understanding of own and others' emotions does not seem to be associated with pain perception, regulation of emotion is. Participants with poor trait self-regulation skills had increased affective responses (both empathic concern and personal distress) to the pain condition and gave higher ratings of pain unpleasantness and intensity. Poorer trait self-regulation was also associated with greater increases in affective

state from the non-pain to the pain conditions. The significant correlation between trait self-regulation and change in affective state (with greater changes indicative of less state regulation) suggests that participants' subjective reports of their self-regulation are reliable. Contrary to expectations, self-regulation scores were negatively correlated with both empathic concern and personal distress. I had hypothesised that self-regulation scores would be negatively correlated with distress only, and not with empathic concern. However, as discussed previously, empathic concern and personal distress responses were very highly correlated, raising doubts about whether the different questions really assessed different constructs. Given the similarity between the empathic concern and personal distress responses, it is unlikely that it would have been possible to find an interaction between self-regulation and type of affective state, or between autism traits and type of affective state, even if such interactions exist.

In summary, autism traits were not correlated with affective states or perceived pain. However, two factors that were both correlated with amount of autism traits in Study 1 predicted affective states and perceived pain: medication use and self-regulation ability. Medication use was associated with heightened general arousal and greater perceived pain. Better self-regulation was associated with lower absolute affective state ratings, and smaller changes in affective state when observing others' pain. Extrapolating these findings, it is possible that individuals with more autism traits, who are more likely to have poor self-regulation and be on medication, may experience heightened general distress. It must be cautioned that the correlations between autism traits and both affective state and perceived pain were not statistically significant; however, these relationships are worthy of further exploration.

Muscle Reactivity

Researchers have proposed two opposing types of muscle reactions to perceived pain: The first is a freezing reaction to avoid possible harm (i.e., a reduction in muscle activity); the second is unconscious, involuntary activity in the muscles, mimicking the observed reactions. In this study, participants experienced small but significant increases in activity in both the FDI and ADM muscles when observing the pain condition relative to the non-pain conditions. This result supports theories of muscle mimicry of observed pain (Lamm et al., 2008; Sonnby–Borgström, 2002), rather than corticospinal inhibition to perceived pain. My study is the only one to look at muscle reactivity in the area that is observed to be hurt. Previous studies have either looked at facial expressions to observing pain (e.g., Bavelas et al., 1986; Lamm et al., 2008) or at increases in muscle reactivity to first-hand pain when also observing another's pain (e.g., Mailhot et al., 2012). The results of the current study show that muscle responses to perceived pain include not only facial expressions of distress or concern, but also muscle activity at the site of perceived injury; in this case, the muscles of the hand.

Two different associations between muscle reactivity and autism traits were possible: The only previous study of muscle reactivity to pain in ASD (Minio-Paluello, Baron-Cohen, et al., 2009) found reduced inhibition of muscle-evoked responses in participants with ASD (they did not measure muscle activity itself). Greater inhibition of muscle-evoked responses is also associated with better cognitive empathy and lower personal distress (Avenanti, Minio-Paluello, Bufalari, et al., 2009). These studies suggest that muscle activity would be heightened in participants with high amounts of autism traits. Other studies have suggested that muscle mimicry communicates concern (Bavelas et al., 1986), and that muscle activity in the presence of noxious stimulation is positively correlated with empathy (Mailhot et al.,

2012; Vachon-Presseau et al., 2011). From this perspective, the empathy-deficit hypothesis of ASD would predict reduced muscle reactivity in response to others' pain.

In fact, amount of autism traits was not correlated with amount of muscle activation or rate of activation change. These results are in agreement with the nonsignificant correlation between autism traits and subjective affective state changes discussed previously. The findings suggest that muscle mimicry to another's pain is intact in ASD, in contrast to the findings of Minio-Paluello, Baron-Cohen, et al. (2009). A potential explanation for the contradictory findings is that these authors investigated muscle-evoked responses rather than muscle reactivity itself, and excluded participants who showed muscle reactivity to the videos. Their decision to exclude these participants likely explains the difference in results, and excluded any possibility of investigating muscle reactivity as empathy. I also found no association between autism traits and rate of change of muscle reactivity. Despite a previous report of slower muscle mimicry of facial emotions in ASD (Oberman et al., 2009), there were no differences in change in muscle activity (i.e., muscle slope) in this sample. Furthermore, medication use – a potential proxy for ASD - was not correlated with amount of activation or the rate of change in activation. In sum, autism traits were not associated with any differences in muscle reactivity.

Affective states (both empathic concern and personal distress) and trait empathy facets (affective empathy, cognitive empathy and self-regulation) were not significantly correlated with muscle activity either. This result was unexpected, as trait empathy has been correlated with mimicry of facial affect in non-pain conditions (e.g., Dimberg & Thunberg, 2012; Sonnby-Borgström et al., 2003) and with the size of a pain-induced muscle flexion reflex (Vachon-Presseau et al., 2011). However, it is not unprecedented. Mailhot et al. (2012) found no significant correlation between M. corrugator supercilii activity and trait empathy when observing others in pain, and Reicherts et al. (2013) found no correlation between M.

corrugator supercilii activity and perceived pain intensity. In non-pain studies of facial mimicry, the correlation between affective states and muscle activity has also not always been upheld: Induced emotion states were not correlated with facial mimicry in a study of facial reactions to basic emotions (Hess & Blairy, 2001). It is possible that current measurement techniques are too crude to detect an association between empathy and mimicry. The non-significant correlation between empathy and EMG activity in this study may be due to the fairly small within-subject changes in muscle activity and large between-subject differences in muscle reactivity within the sample. The changes in muscle activity were likely smaller in this study than in previous studies because the participants did not experience physical pain themselves, unlike many other studies where participants received a painful stimulus such as a mild shock while viewing empathy-inducing stimuli (e.g., Caes et al., 2012; Mailhot et al., 2012; Reicherts et al., 2013).

Surprisingly, muscle reactivity did not differ between the FDI and ADM muscle areas. The ADM muscle did not act as a control muscle as was intended; rather, it seems that participants tensed their whole hand in response to the stimulus. This finding was not correlated with autism traits, so it is not the case that participants higher in autism traits had a more generalised muscle response than those lower in autism traits. General tension, as was found in this study, could be an indication of distress rather than empathy-related muscle mimicry. This possibility needs further investigation. For future studies, the FDI on the opposite hand may serve as a better control muscle. Nonetheless, the results can still be interpreted, as muscle activity in the non-pain conditions served as a control.

In summary, the pattern of muscle reactivity was consistent with a mimicry response, with muscle reactivity increasing as observed pain increased. Muscle mimicry was not associated with autism traits, suggesting intact, but not heightened, physiological responses to

observed pain in ASD. Physiological responses to observed pain were also measured at the autonomic level, which I turn to next.

Autonomic Arousal

Resting state autonomic arousal. Parasympathetic (cardiac vagal control) and sympathetic arousal (pre-ejection period and skin conductance), as well as heart rate (influenced by both autonomic branches), was measured during a 2-minute baseline. A measure of cardiac vagal control unbiased by respiration was estimated by measuring resting state RSA and using the residuals of a regression predicting RSA from respiration rate and tidal volume. Participants had heart rate, skin conductance, pre-ejection period and RSA scores within previously reported normal ranges (de Geus & van Doornen, 1996), which supports the validity of the measurements. Two different sets of questions were asked in this part of the study. First, does resting state arousal predict amount of autism traits and empathic regulation ability? Secondly, are autonomic arousal levels in response to sensory pain stimuli correlated with autism traits? I will first discuss the association between resting state autonomic measures and autism traits, and then the association between resting state autonomic measures and state and trait empathy. The second question is dealt with in the section *Autonomic reactivity to perceived sensory pain.*

Autism traits. The polyvagal theory proposes that autism is characterised by reduced cardiac vagal control, leading to "atypical social and emotion behaviors" (Porges et al., 2013, p. 261). Contrary to predictions of the polyvagal theory, there was no correlation between amount of autism traits and resting state cardiac vagal control. This study is one of the largest samples in which the association between autism traits and RSA has been tested, and corresponds to previous findings concluding that resting state parasympathetic regulation in ASD is not affected (Benevides & Lane, 2015; Levine et al., 2012; Schaaf, Benevides, Leiby,

& Sendecki, 2015; Sheinkopf et al., 2013). Studies of specific genetic syndromes associated with ASD, such as fragile X syndrome, have more consistently found atypical parasympathetic regulation (Klusek, Roberts, & Losh, 2014), but parasympathetic regulation does not seem to be associated with general autism traits.

Because of the importance that the neurovisceral integration model and polyvagal theory place on parasympathetic regulation, and because specialised equipment is needed to measure sympathetic cardiac effects, there are very few studies of resting state cardiac sympathetic arousal in ASD. Most studies have only investigated resting state parasympathetic arousal, or general arousal as measured by skin conductance, which does not exclusively reflect cardiac sympathetic arousal (Cacioppo et al., 2007). This study is one of the few studies to simultaneously investigate sympathetic and parasympathetic cardiac regulation in ASD. Sympathetic cardiac arousal was measured by calculating the pre-ejection period. Similar to previous cardiac sympathetic research in ASD, there was no correlation between resting state cardiac sympathetic activity and autism traits (Althaus et al., 2004; Schaaf et al., 2015). However, resting state heart rate was positively correlated with amount of autism traits. This effect is likely due to antidepressant use, as once participants on antidepressants were excluded, heart rate was no longer significantly correlated with amount of autism traits. In support of this conclusion, previous studies have reported medication effects on heart rate in participants with ASD (Daluwatte et al., 2012; Mathewson et al., 2011), and specific effects of antidepressants on both sympathetic (Licht, Penninx, & de Geus, 2012) and parasympathetic regulation (Kemp et al., 2014; Licht et al., 2010) in the population at large. It is not clear whether the increased resting state heart rate stems from low parasympathetic arousal or high sympathetic arousal (or both) in the current participant group, as neither of these indices were significantly correlated with AI or with medication. Either cause is conceivable as antidepressants such as selective serotonin reuptake inhibitors

have noradrenergic and serotonergic effects on brainstem nuclei, influencing both sympathetic and parasympathetic regulation. Other antidepressants such as tricyclic antidepressants may increase norepinephrine concentrations in the sinoatrial node of the heart itself, thereby directly increasing heart rate (Licht et al., 2010, 2012).

In sum, this study found no conclusive evidence for atypical autonomic nervous system control at rest in participants with high amounts of autism traits. Heightened heart rate in participants with high amounts of autism traits is likely due to the use of medication, rather than abnormalities in the central autonomic network.

Empathy. In Chapter 2 I argued that, if the social behaviour and emotion predictions of the neurovisceral integration model and polyvagal theory are correct, cardiac vagal control will be positively correlated with self-regulation ability as well as empathic concern, and negatively related to personal distress. Corresponding to my predictions, resting state autonomic arousal predicted changes in personal distress on the day of testing. Relative to autonomic co-inhibition (i.e., low sympathetic and parasympathetic arousal), the combination of high resting state pre-ejection period (i.e., low sympathetic arousal) and high resting state cardiac vagal control (high parasympathetic arousal) predicted reduced changes in personal distress in participants. In contrast, empathic concern did not differ between these autonomic arousal groups. These findings support the argument that heightened cardiac vagal control and reduced sympathetic arousal indicate the capacity for effective self-regulation (e.g., Musser et al., 2011; Thayer & Lane, 2000). Similarly, heart rate was significantly correlated with trait self-regulation, which could indicate a possible effect of cardiac regulation on emotion regulation during distress. However, heart rate was no longer significantly correlated with self-regulation when participants using antidepressants were excluded from the analysis. Furthermore, resting state cardiac vagal control was not correlated with self-reported trait self-regulation, or with trait affective empathy. It is unclear why this study found non-

significant correlations when other studies (Butler et al., 2006; Huffman et al., 1998) have found associations between autonomic arousal and emotion regulation. Participant responses had a suitable range, so it is unlikely that nonsignificant results are due to floor or ceiling effects on any of the questionnaires. One possible reason why cardiac autonomic regulation was not significantly correlated with trait empathy is that participants are not always reliable retrospective reporters of their own emotions (Stellar et al., 2015). Measures of behavioural self-regulation, such as persistence on difficult tasks (Segerstrom & Nes, 2007) or informant reports of problem behaviour (Hinnant & El-Sheikh, 2009; Salomon et al., 2000) have found associations between resting state autonomic arousal and self-regulation, and may be useful additions to self-reports of emotion in future studies.

Based on the results of previous studies, I investigated whether higher resting state cardiac vagal control would predict better cognitive empathy (Bal et al., 2010; Muhtadie et al., 2015). In contrast to previous research, neither resting state cardiac vagal control, nor cardiac sympathetic arousal was correlated with trait or performance cognitive empathy. These contrasting results may be explained by the fact that Bal and colleagues (2010) only found a correlation between cognitive empathy and cardiac vagal control in their ASD group, not the neurotypical controls. In this context, cardiac vagal control may have been a marker for increased severity of the disorder (children with more severe ASD may also have been less likely to sit still for the resting state measurement, potentially compromising the results) or severity of language impairment. Cardiac vagal control has been correlated with pragmatic language in previous studies (Klusek, Martin, & Losh, 2013; Patriquin et al., 2013), and language is strongly correlated with more complex forms of cognitive empathy (Astington, 2005; Astington & Jenkins, 1999). Correspondingly, the task on which cardiac vagal control predicted cognitive empathy in Muhtadie and colleagues' study, the Reading the Mind in the Eyes Test, has been criticised as being a mental state vocabulary test (E. Peterson & Miller,

2012). In both these studies, then, language may have been a confounding factor. More research is needed to disentangle the association between parasympathetic arousal and language, and parasympathetic arousal and cognitive empathy.

Autonomic reactivity to perceived sensory pain. Apart from measuring baseline autonomic arousal, I also measured sympathetic responsiveness to perceived pain. Parasympathetic responsiveness was not measured in this study as the videos were too short for the minimum recording time needed to calculate RSA. The hypothesis that sympathetic arousal would be heightened during observation of the painful conditions was partially upheld: Skin conductance increased from non-pain to pain conditions, though cardiac autonomic arousal did not differ between conditions. Previous studies to investigate sympathetic response in a sensory pain paradigm measured pupil dilation (Azevedo et al., 2013) and skin conductance response (Fusaro, Tieri, & Aglioti, 2016; Gu et al., 2015; Hein et al., 2011). With the exception of Gu et al. (2015), these studies found significantly increased sympathetic activity to pain conditions in neurotypical participants; similar to the findings of this study. The increase in skin conductance suggests that the stimuli successfully induced an affective response in the observers. I will return to the discussion of cardiac arousal later in this section.

The overriding aim of this study was to test whether amount of autism traits would be related to physiological indices of affective arousal. Recall that some theorists have proposed a general deficit in empathy in ASD (Baron-Cohen, 2009; C. Gillberg, 1992) – which would be reflected in reduced sympathetic responses to observed pain – whereas others have argued that affective empathy is enhanced in ASD (A. Smith, 2009) – as would be seen in heightened sympathetic responses to others' pain. In contrast to both sets of theories, amount of autism traits was not correlated with autonomic activity (heart rate, pre-ejection period or skin conductance) to perceiving others' sensory pain. Moreover, medication use did not

predict changes in heart rate, pre-ejection period or skin conductance beyond its influence on resting state arousal. I also investigated the possibility of different autonomic habituation rates in participants with more autism traits. It could be argued that, if participants with high amounts of autism traits have heightened affective empathy or distress, they would also show diminished habituation responses. However, although arousal differed between the experimental blocks, there were no interactions between block and amount of autism traits in any of the autonomic measures. A study using a similar paradigm found that individuals with ASD had greater skin conductance responses than neurotypical controls when viewing another's pain (Gu et al., 2015). However, a difference between their study and this one is that their neurotypical participants did not show an increase in skin conductance responses to the pain condition. This unusual result may have been the reason behind the group differences found in their study. Overall, the autonomic results support intact, but not heightened, affective empathy in participants with high amounts of autism traits.

It is unclear why no significant changes in heart rate or pre-ejection period were detected in the pain condition. No previous studies have, to my knowledge, used pre-ejection period to quantify sympathetic activity in this paradigm, so the cardiac results cannot be directly compared to previous findings. The absence of published results may be because previous studies have failed to find significant changes in these measures. Alternatively, it may be that the stimuli used in this study were not sufficiently arousing to produce a clearly discernible and robust cardiac sympathetic response. Some previous studies examining heart rate changes to perceived pain versus neutral or positive conditions found reductions in heart rate to the pain videos (Craig & Lowery, 1969; Fusaro et al., 2016); however, these studies used live actors or a virtual reality setting, and thus the stimuli may have been much more arousing than videos of sensory pain. Although participants' self-reports indicated that the stimuli induced feelings of empathy and distress, mild feelings of empathy and distress may

not be associated with large cardiac sympathetic responses. In summary, cardiac autonomic arousal did not differ between conditions. The videos featuring sensory pain elicited a heightened skin conductance response that was not associated with amount of autism traits.

Coherence between autonomic and subjective measures of empathy. It was predicted that greater subjective feelings of personal distress and diminished trait self-regulation would be reflected in heightened sympathetic arousal. Contrary to what was hypothesised, personal distress and self-regulation ratings were not significantly correlated with sympathetic arousal. Previous studies that have investigated the relationship between self-reported empathy and sympathetic arousal have obtained mixed results, with one study finding a significant correlation (Hein et al., 2011) and others no correlation (de Coster, Verschuere, Goubert, Tsakiris, & Brass, 2013; Fusaro et al., 2016; Lamm et al., 2008). These differences may be due to differences in the way affect is measured, differences in the participant samples, or differing intensity of the stimuli. For example, previous studies have shown that significant correlations between subjective and physiological affective states are only present during fairly intense emotional stimuli (Rosenberg & Ekman, 1994) or emotional responses (Schaefer, Larson, Davidson, & Coan, 2014). Hence, the stimuli used in this study may not have evoked a large enough response to be able to find coherence of responses across measurement levels. Even under amplified emotional conditions, different measurement levels of emotion are only weakly associated (Reisenzein, 2000), leading several researchers to argue that physiological and subjective reports measure different aspects of affective experience, and should not be assumed to be interchangeable (Evers et al., 2014; Mauss & Robinson, 2009). This argument will be discussed further in Chapter 8; the conclusion to be drawn here is that subjective and physiological responses can be meaningfully interpreted separately, and need not be associated. The addition of further

levels of measurement, and improved measurement in the current levels of analysis, may improve coherence in future studies.

Limitations and Future Directions

Some limitations temper the impact of the study. First, the ADM muscle did not act as a non-affected control muscle as was expected; rather, findings indicate that participants tensed the whole hand while observing painful stimulation, activating both FDI and ADM areas. The ADM was chosen because it was used as a control muscle in previous studies (e.g., Minio-Paluello, Baron-Cohen, et al., 2009); however, using the FDI muscle on the opposite hand may be a better option for a control muscle. Despite the unanticipated activation of the ADM, the FDI results can still be interpreted, as muscle activity in the non-pain conditions served as a comparison to activity during pain observation.

I used existing experimental videos in this study that featured only white hands; however, the sample was comprised of participants from several race groups. Studies have shown that arousal to viewing other-race pain is less than own-race pain (Avenanti et al., 2010; Azevedo et al., 2013). The other-race effect could have contributed to a smaller overall empathy effect. However, race was not associated with amount of autism traits, so any reduced effect due to race should not have affected the nature of the relationship between amount of autism traits and arousal.

Lastly, it is possible that the absence of a difference in the pre-ejection period between pain and non-pain conditions may be because the measurement time (4 s) was too short to get a reliable reading for the pre-ejection period. The videos have been used successfully in previous studies. Thus, to keep the results comparable, the original video length was kept. This limitation is addressed in the next study, where longer measurement epochs are used. Limitations that apply to all of the studies will be discussed in the general

discussion in Chapter 8. Despite these limitations, the study offers valuable new insights into autonomic arousal during empathy.

Summary and Conclusions

The aim of this study was to investigate whether autism traits are correlated with empathy for others' sensory pain. Subjective empathic concern, muscle reactivity, and sympathetic autonomic reactivity during empathy-induction was measured, and correlated with amount of autism traits. Overall, participants displayed increased muscle activity and general arousal – as indicated by skin conductance - to viewing others in pain, and reported the perceived pain as fairly intense and unpleasant. Empathic concern and personal distress responses were highly similar, so that these two sets of responses could not be differentiated from each other.

This study did not find that autism traits are significantly associated with reduced physiological or subjective affective responses to others' physical pain. At the subjective level, affective state (both empathic concern and personal distress) and pain perception were not correlated with autism traits. Similar to Study 1, these results argue against a global empathy deficit in ASD. Furthermore, the self-report results suggest that some individuals with high amounts of autism traits may be more prone to experiencing heightened affective arousal: Being on medication and having poorer self-regulation ability were correlated with greater affective reactions and higher ratings of pain unpleasantness and intensity. To tie this in to the empathy imbalance theory of autism (A. Smith, 2009, 2010), autism traits do not seem to be associated with higher subjective empathic concern/distress *per se*, though poor self-regulation in this group may lead to heightened subjective experience of affective states. However, medication and poor self-regulation were associated with heightened affective arousal in general, not only to empathy-related responses. Thus, the weight of the evidence

from this study does not support the proposition of heightened affective *empathy* in ASD either. Similarly, at the physiological level, the results support the conclusion that empathy for sensory pain is intact in ASD, and do not provide evidence for hyper-arousal in ASD: Muscle reactivity to the empathy-for-pain videos was not significantly correlated with amount of autism traits, and neither was sympathetic reactivity. The finding that participants on medication and those with poor trait self-regulation show heightened subjective reactivity to stimuli was not corroborated at the autonomic or muscular levels, which may indicate that it is the perception of own emotion that is altered in these groups rather than underlying physiology. Alternatively, as resting state arousal was controlled for in the models, the effect of medication may not be visible beyond its influence on resting state arousal, but it is notable that higher resting state stress arousal was significantly related to higher arousal during pain observation. Thus, it is plausible that medication use may heighten resting state arousal, thereby increasing autonomic and subjective arousal to stimuli. The implication of the affective state results for current theoretical perspectives on ASD is discussed further in Chapter 8.

With regards to predictions of the neurovisceral integration and polyvagal theories, I investigated the correlation between resting state autonomic arousal and state as well as trait empathy. In particular, I hypothesised that there would be a correlation between resting state autonomic arousal and dispositional self-regulation, which would in turn lead to greater feelings of empathic concern, as well as less personal distress and sympathetic arousal, at observing others' pain. This study provides limited support for the idea that resting state autonomic reactivity is an indicator of the capacity for empathic concern. The combination of low sympathetic arousal and high parasympathetic arousal at rest predicted reduced changes in self-reported personal distress, but not empathic concern, to painful conditions. The effect remained when participants on antidepressants were excluded. This result supports the

hypothesis that high resting state parasympathetic arousal is an indicator of the capacity for self-regulation. However, resting state sympathetic and parasympathetic arousal did not predict absolute affective state levels, as would be predicted from the polyvagal theory. Additionally, there was little evidence in this study that either cardiac sympathetic or parasympathetic arousal at rest is correlated with amount of autism traits. Though heart rate was correlated with autism traits, this relationship was not seen in other autonomic arousal measures, and was not upheld once participants taking antidepressants were excluded from the analysis. Thus, rather than directly influencing or reflecting capacity for social engagement, resting state parasympathetic arousal may reflect emotion regulation, which is but one part of social engagement. Furthermore, atypical autonomic arousal does not seem to be a general characteristic of the broader autism phenotype.

In conclusion, the current study found no evidence for deficits in empathy for sensory pain in ASD. These findings diverge from portrayals of individuals with ASD as lacking in empathic responses (Baron-Cohen, 2009; C. Gillberg, 1992; Hobson et al., 2009). Study 3 tests the association between autism traits and empathy when greater demands are placed on cognitive empathy.

Chapter 7.

Study 3: Empathy for Facial Expressions of Pain

> Look into someone else's face, and see the consciousness in it, and a particular shade of consciousness. You see on it, in it, joy, indifference, interest, excitement, torpor, and so on . . . Do you look into *yourself* in order to recognize the fury in *his* face?
> (Wittgenstein, 1967, p. 40e [original emphasis])

This chapter examines responses to facial expressions of pain. Study 2 found no evidence for deficits in affective empathy or empathic concern for sensory pain in ASD. However, though the paradigm used in that study is well-tested, it is not the same as perceiving pain in everyday life. One aspect of difference is that, in everyday life, only the communication of pain may be visible to the observer, and not the painful stimulus. Non-verbal communication of pain, for example through facial expressions, may not be correctly interpreted by individuals with high amounts of autism traits if they have difficulties with recognising facial expressions of pain; similar to what was shown in Study 1 for basic emotions. Thus, the first aim of Study 3 was to expand on the empathy-for-pain paradigm used in Study 2 by presenting participants with facial expressions of pain, rather than the sensory application of pain. Similar to the design of Study 2, I tested the correlation between empathy for facial expressions of pain and amount of autism traits. Second, as understanding of others' emotions is also closely related to understanding of own emotions, an important part of this study was to test the correlation between alexithymia and empathic concern; particularly, whether alexithymia would mediate a potential relationship between autism and empathic concern.

Third, I wished to test whether, if participants were specifically asked to take the perspective of the other person – which participants with high amounts of autism traits may be less likely to do spontaneously, as was shown in Study 1 – there would be a difference in affective empathy at the physiological level or empathic concern at the subjective level.

Fourth, Study 2 found that two factors related to having ASD, namely being on medication and having poorer self-regulation ability, were correlated with greater affective reactions and higher ratings of pain unpleasantness and intensity. I wished to test whether these associations would be upheld in another empathy-for-pain study, and one that makes greater demands on cognitive empathy.

Lastly, another aim of Study 3 was to replicate the results pertaining to the neurovisceral integration and polyvagal theories. Study 2 found that the combination of low sympathetic arousal and high parasympathetic arousal at rest, relative to autonomic co-inhibition, predicted reduced changes in self-reported personal distress to painful conditions, but not absolute affective state levels (neither empathic concern nor distress) or trait self-regulation. Additionally, changes in sympathetic arousal to the empathy-inducing stimuli did not predict self-reported empathic concern or personal distress. Study 3 sought to replicate and expand these results by using longer-duration empathy-for-pain videos so that both sympathetic and parasympathetic reactivity to perceived pain could be studied.

Methods

Design

The study followed a multilevel correlational design, investigating within-subject changes in physiological and subjective affective states, and correlations between participants' autism traits and their empathic responses. Participants were shown recorded facial expressions of pain under two different perspective-taking instructions: For half of the stimuli, participants were instructed to imagine how the person experiencing the pain is feeling (imagine other). For the rest of the stimuli, participants were instructed to imagine how they would feel if they were undergoing the painful stimuli (imagine self). Affective state, facial muscle activity, cardiac vagal control, pre-ejection period, heart rate, and SCL were predicted from the perspective-taking condition and participants' amount of autism traits, as well as cognitive and demographic covariates. Self-reported affective responses and resting state physiology were used to predict physiological arousal to the videos.

Participants

The full laboratory sample participated in this study (N = 98, see Chapter 4, *Participants*, p. 50). Two participants were excluded from the analysis, one because they were answering randomly, and one because of an abnormally slow response time on all tasks (> 3 *SD*s from mean). This left 96 participants who participated in the study, of which one only completed one cycle of the stimulus material (the available data for this participant were used). Of the 96 participants, one was excluded from EMG analyses because of extremely low EMG activity at all time points (N = 95). Furthermore, due to equipment failure, autonomic data were not available for one participant (N = 95). Additionally, two participants had B-points on the ICG that were not clearly identifiable, and were not included in any of the pre-ejection period analyses. Eleven participants had SCL quality ratings below 4/10 (see

p. 58 for a description of the ratings), and were left out of all SCL analyses. Refer back to Figure 1, p. 52, for the research participation flowchart.

Materials and Measures

Previously reported measures. AI scores, as calculated from ADOS-2 and AQ scores in Study 1, were used as an indicator of amount of autism traits. For dispositional empathy, the trait affective empathy, trait cognitive empathy, and trait self-regulation aggregates calculated in Study 1 were used (see Table 5, p. 84). Again, performance cognitive empathy (rather than trait cognitive empathy) was used as the primary indicator of cognitive empathy in the analyses. Total scores on the 20-item Toronto Alexithymia Scale (TAS-20) were used to indicate alexithymia. Affective states (empathic concern and personal distress) and perceived pain during the videos were measured as described in Chapter 6, *Affective states and perceived pain,* p. 115.

Video stimuli. The stimuli featured male and female actors initially showing a neutral expression (1-3 s; see Figure 18), followed by an expression of pain. All video clips have been used in previous studies to measure empathic concern, perceived pain and physiological responses to pain (Lamm et al., 2007, 2008). The video clips lasted approximately 6 s.

Figure 18. Clips from the painful facial expression videos showing the initial neutral and later painful facial expressions. From "The Neural Substrate of Human Empathy: Effects of Perspective-Taking and Cognitive Appraisal" by C. Lamm, C. D. Batson and J. Decety, 2007, *Journal of Cognitive Neuroscience, 19*, p. 44. Copyright 2007 by the MIT Press.

Electromyogram (EMG). Surface EMG electrodes were placed on the left side of the face over the M. orbicularis oculi, M. corrugator supercilii and M. medial frontalis areas according to international guidelines (Fridlund & Cacioppo, 1986). The reference electrode was placed on the forehead below the hairline. Stimulus-evoked EMG activity was scored as the change in activity from a 1 s prestimulus baseline and was averaged over 200 ms periods from 0 to 3.4 s to create a reasonable number of measurements for subsequent calculations (similar to Dimberg & Thunberg, 2012; Dimberg et al., 2000). Trials that had EMG activity above 8 µV during the baseline period or activity above 30 µV or below -30 µV during stimulus presentation (0.20% of data) were excluded to prevent large resting state differences and extreme values that are unlikely to be involuntary reactions (Reicherts et al., 2012). The average EMG amplitude during the expression of pain (1.4 – 3.4 ms) was calculated as a measure of response magnitude. To get an indication of response latency at pain onset, the slope of the average EMG activity over the consecutive 200 ms periods from time 0 (start of pain) to 2.4 s was calculated (Malmo & Davis, 1956; Malmo & Malmo, 2000).

Autonomic activity. Heart rate, RSA, SCL and pre-ejection period activity were recorded during the 2-minute baseline period, as well as over the length of each of the four blocks (each approx. 105 s). As in Study 2, EKG artefacts made up 1.12% of the data and were corrected by cubic spline interpolation (Berntson & Stowell, 1998; Vrije Universiteit, 2015). Beats with bad ICG signal quality were automatically detected and removed from individual complexes (0.54% of data; as per Sherwood et al., 1990; Willemsen et al., 1996). Ensemble-averaged ICG complexes were manually inspected and no distorted complexes were found. All complexes were included in averaging. For the SCL analyses, 0.29% of the data were identified as artefacts and not included in the calculation of the average (as recommended by the Society for Psychophysiological Research Ad Hoc Committee on Electrodermal Measures, 2012). To calculate cardiac vagal control, RSA was predicted from respiration rate and tidal volume. The residuals of that regression were used as an indicator of cardiac vagal control.

Procedure

As in Study 2, participants were asked not to smoke, eat, exercise, or drink caffeinated beverages or alcohol for 2 hours prior to the experiment. The experiment was conducted in a temperature and lighting-controlled room. On arrival at the laboratory, the VU-AMS and ActiveTwo electrodes were fitted. Participants were separated from the researcher by a curtain, through which the researcher could monitor whether they were paying attention to the stimuli and not moving unduly. Participants were asked to remain seated and rest their left hand (to which the skin conductance electrodes were attached) on the table throughout the procedure. Participants listened to music (Clair de Lune, Schmalfuss, 2010) for five minutes, after which two minutes of resting state data were collected while participants sat with their eyes closed.

The video clips were presented using E-Prime 2 (Psychology Software Tools, Pittsburgh, PA) on a 19-inch, 4:3 aspect ratio monitor, positioned approximately 65cm away from the participants. Participants were told that the video clips showed patients experiencing painful auditory stimulation due to medical treatment. Video-clips were preceded by one of two instructions: Participants were either told to imagine how they would feel in that situation (imagine self) or how the patient felt (imagine other; Lamm et al., 2007). Six clips were shown in a block, with two blocks each of the two perspectives (24 videos in total). The clips were randomly assigned to one of the two conditions. The order of the blocks and of the clips within a block were randomised. Clips that were shown in the imagine-self condition were never shown in the imagine-other condition, and vice versa. Between trials, participants viewed 10 s luminance-matched scrambled static images to minimise muscular and arousal responses to changes in luminance (Lamm et al., 2007, 2008). Stimuli were preceded by a 1 s display of a centred fixation cross. At the end of each block, participants rated the intensity and unpleasantness of the pain shown in the videos, as well as their level of empathic concern for the targets and their personal distress. Participants were asked to remain seated throughout the experiment and to refrain from talking or moving excessively.

Data Analysis

Descriptive statistics and zero-order correlations between the physiological and subjective variables are reported. All analyses were preceded by an investigation of the distribution of the data and inspection for outliers. Models were also examined for multicollinearity, outliers, heteroscedasticity and other patterning of the residuals. Preliminary linear random-effects models with participant ID as the random intercept were run to assesses whether the stimuli elicited significant changes in the various physiological indices. Next, a series of linear mixed-effects models were run to predict subjective and

physiological responses.

First, two separate mixed-effects models were done to predict pain perception and affective state from condition (self or other), AI, self-regulation and performance cognitive empathy. The outcome variable for pain perception was rating (where 1 = *not at all* and 7 = *extremely*), and pain unpleasantness versus pain intensity was entered as a binary predictor variable. Thus, pain perception refers to both pain unpleasantness and pain intensity. Similarly, the outcome variable for the affective state responses was rating (where 1 = *not at all* and 7 = *extremely*) and state type (concern versus distress) was coded as a binary predictor variable. To model pain perception, participant ID was used as the random intercept, with condition and perception type (intensity, unpleasantness) and their interaction as random slopes. To model affective state, participant ID was used as the random intercept, with condition and state (distress, empathic concern) and their interaction as random slopes.

Second, muscle reactivity was predicted from condition, muscle (M. corrugator, M. frontalis, M. orbicularis), AI, self-regulation and performance cognitive empathy. Separate analyses were done for muscle amplitude and muscle slope. Third, separate mixed-effects models were done to predict pre-ejection period, SCL, vagal cardiac control, and heart rate from the predictors described above. Video cycle (first or second round of perspective-taking), medication use and alexithymia were included as control variables in all analyses. Additionally, baseline arousal was added as a control variable in each of the autonomic arousal models.

For the EMG analyses, participant ID was used as the random intercept with the interaction between muscle and condition as random slopes. For the various indices of physiological arousal, participant ID was again used as the random intercept, with condition as random slope. Similar to Study 1, if a model did not converge, an iterative simplification process was followed (Bates, Kliegl, et al., 2015): First, a simpler random slopes structure

without an interaction was tried, and if this model also did not converge, a nested intercept structure was attempted. Where within-group variance was zero and model fit indices indicated a poor fit with a more complex model, responses were aggregated across conditions, as detailed in the *Results* section.

Results

Self-Reported Affective State and Perceived Pain

Are subjective indices of affective empathy and empathic concern correlated with amount of autism traits?

Hypothesis IV: Pain perception (unpleasantness and intensity) will be positively correlated with amount of autism traits once alexithymia is controlled for.

Hypothesis V: Amount of autism traits will be negatively correlated with empathic concern and positively correlated with personal distress.

What other factors are associated with pain perception and empathic concern (versus personal distress)?

Hypothesis VIII: Self-regulation scores will be positively correlated with empathic concern and negatively correlated with perception of pain and personal distress. In other words, better self-regulation will be associated with higher empathic concern and lower personal distress and perceived pain intensity/unpleasantness.

Hypothesis IX: Cognitive empathy will be positively correlated with perceived pain and empathic concern.

Pain perception. On average, participants reported high pain intensity and unpleasantness to both the imagine-self (M_I = 5.35, SD_I = 1.29 and M_U = 5.45, SD_U = 1.31, respectively) and imagine-other (M_I = 5.39, SD_I = 1.27 and M_U = 5.48, SD_U = 1.25, respectively) conditions. Perceived intensity and unpleasantness ratings were highly correlated (r_{self} [94] = .85, $p < .001$; r_{other} [94] = .83, $p < .001$). A linear mixed-effects model with medication, condition (imagine self or imagine other), perception type (unpleasantness or intensity), cycle (one or two), AI scores, performance cognitive empathy, self-regulation and their interactions was run to predict perceived pain ratings. The results of the final model are presented in Table 23.

Table 23

Linear Mixed-Effects Model of Pain Perception

Fixed effects	*SS*	*MS*	df_{effect}	df_{error}	*F*-value	Probability	
Medication	6.59	6.59	1	92.35	12.48	.001	**
Cycle	5.80	5.80	1	475.10	10.98	.001	**
AI	4.68	4.68	1	92.98	8.85	.004	**

Random effects					
Group	*N*	Slope	Variance	Correlation	
ID	96	(Intercept)	0.94		
		Imagine self	0.08	- .01	
		Pain unpleasantness	0.04	- .01	.58
		Imagine self *Pain unpleasantness	0.00	.26	- .93 - .76
Residual	764		0.53		

Note. Random effects: ID (intercept), condition (slope), pain perception (slope). R^2_M = .10, R^2_C = .69. AI = Autism Index.

*$p < .05$, **$p < .01$, ***$p < .001$.

Medication, cycle and AI significantly predicted pain ratings (see Figure 19). Medication use was associated with significantly higher perceived pain, **β** = 0.98, *SE* = 0.28, *t* (92.4) = 3.53, $p \leq .0006$. Perceived pain ratings were higher in the second cycle than the first, **β** = 0.18, *SE* = 0.05, *t* (475.1) = 3.13, $p \leq .0009$. AI scores were negatively correlated with perceived pain, **β** = - 0.33, *SE* = 0.11, *t* (93) = -2.98, $p \leq .004$. There were no significant interactions. Condition, self-regulation, performance cognitive empathy and perception type did not significantly predict perceived pain.

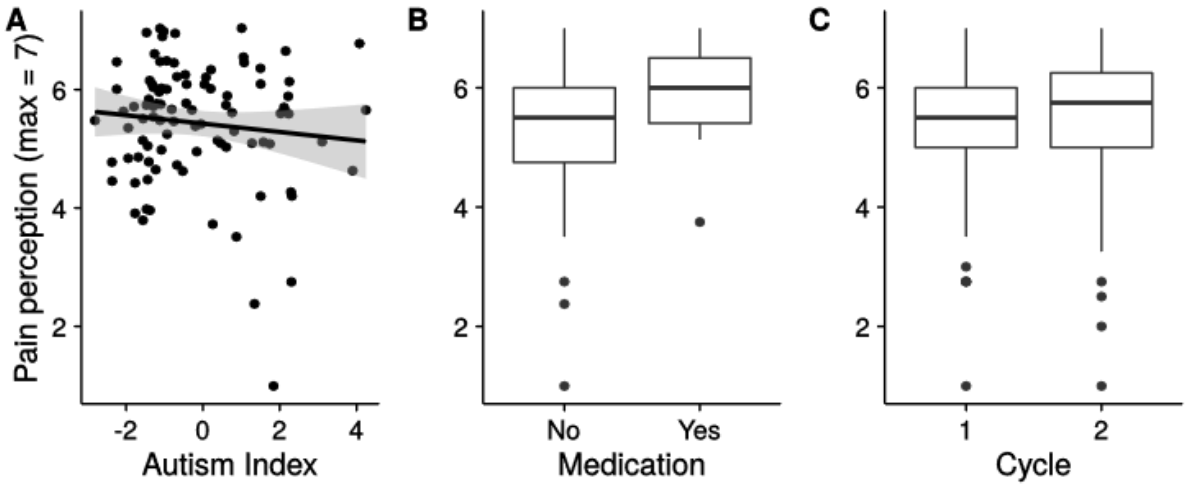

Figure 19. AI (A), medication (B) and cycle (C) significantly predicted pain ratings. There were no significant differences between unpleasantness and intensity ratings. Shaded areas indicate 95% confidence intervals around the prediction. The lower and upper whiskers of the box plot represent the values within 1.5 times the interquartile range.

Affective state ratings. On average, participants reported low to moderate levels of empathic concern and personal distress during the imagine-self (M_{EC} = 3.78, SD_{EC} = 1.60 and M_{PD} = 3.35, SD_{PD} = 1.63) and image-other conditions (M_{EC} = 3.83, SD_{EC} = 1.61 and M_{PD} = 3.32, SD_{PD} = 1.64). Internal consistency for state empathic concern was very high at each of the affective state rating times (αs = 0.91, 0.93, 0.94, 0.96; 95% CIs [0.82, 1.00], [0.85, 1.02],

[0.87, 1.03], [0.88, 1.03]), indicating that item responses were near identical. State personal distress had similarly high internal consistency at each time point (αs = .96, .96, .97, .97; 95% CIs [0.90, 1.01], [0.91, 1.01], [0.93, 1.02], [0.92, 1.02]). Additionally, state empathic concern and personal distress were highly correlated for each condition (r_{self} [94] = .87, $p < .001$, r_{other} [94] = .88, $p < .001$).

Affective state responses were first predicted from medication use; the interaction between state type (concern, distress), condition and AI; the interaction between state type and self-regulation; and the interaction between performance cognitive empathy and state type. Medication use, state type, AI and self-regulation significantly predicted affective state ratings in this model, $R^2_M = .22$, $R^2_C = .88$ (see Table 24 and Figure 20).

Table 24

Linear Mixed-Effects Model of Affective State

Fixed effects	*SS*	*MS*	df_{effect}	df_{error}	*F*-value	Probability	
State	14.88	14.88	1	93.15	44.65	< .001	***
Medication	1.78	1.78	1	90	5.34	.023	*
AI	4.44	4.44	1	90	13.31	< .001	***
Self-regulation	7.05	7.05	1	90	21.15	< .001	***

Random effects					
Group	*N*	Slope	Variance	Correlation	
ID	94	(Intercept)	1.84		
		Imagine self	0.06	- .38	
		Distress	0.36	- .12	.42
		Imagine self *Distress	0.01	.37	-.92 -.02
Residual	752		0.33		

Note. Random effects: ID (intercept), condition (slope), affective state (slope). AI = Autism Index.

*$p < .05$, **$p < .01$, ***$p < .001$.

On average, participants reported less personal distress than empathic concern to the videos, **β** = - 0.49, *SE* = 0.07, *t* (93.15) = - 6.68, $p < .001$. Participants using medication had significantly higher affective state ratings, **β** = 0.85, SE = 0.37, *t* (90) = 2.31, $p \leq .023$. Affective state ratings were negatively correlated with AI scores, **β** = - 0.60, *SE* = 0.16, *t* (90) = - 3.65, $p \leq .0004$, and with self-regulation ability, **β** = - 0.67, *SE* = 0.15, *t* (90) = - 4.60,

$p < .001$. There were no interactions, no difference between cycles, and no correlation between affective state and performance cognitive empathy.

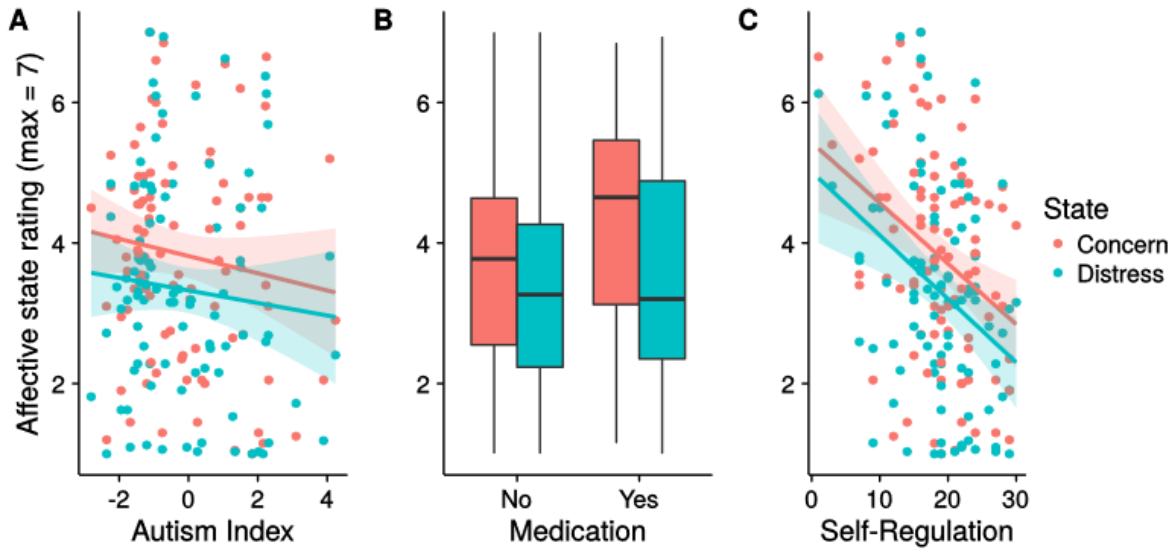

Figure 20. Significant predictors of affective state arousal to facial pain. AI (A), medication use (B), self-regulation (C), and state type (concern versus distress) significantly predicted affective state scores when alexithymia was not controlled for. Shaded areas indicate the 95% confidence intervals around the prediction. The lower and upper whiskers of the box plot represent the values within 1.5 times the interquartile range.

In a second model, alexithymia was entered first as a fixed effect, followed by the other fixed effects as described above. In this model, neither AI scores (**β** = - 0.28, *SE* = 0.19) nor medication (**β** = 0.67, *SE* = 0.35) significantly predicted affective state (see Table 25). Alexithymia was significantly negatively correlated with affective state (both empathic concern and personal distress), **β** = - 0.54, *SE* = 0.16. Self-regulation scores were still significantly negatively correlated with affective state, **β** = - 0.71, *SE* = 0.14. Similar to the previous model, participants reported less personal distress than empathic concern to the videos, **β** = - 0.49, *SE* = 0.07. There were no significant interactions between affective state type (empathic concern or personal distress) and any of the other predictors. This model

predicted a greater amount of the variance in affective state than did the first model, R^2_M = .29, R^2_C = .88[12]. The significant interactions are depicted in Figure 21.

Table 25

Linear Mixed-Effects Model of Affective State, Controlling for Alexithymia

Fixed effects	*SS*	*MS*	df_{effect}	df_{error}	*F*-value	Probability	
State	14.87	14.87	1	93.15	44.62	< .001	***
Medication	1.20	1.20	1	89.01	3.59	0.061	
Alexithymia	3.85	3.85	1	89.01	11.55	< .001	***
AI	0.74	0.74	1	89.01	2.21	0.140	
Self-regulation	8.81	8.81	1	89.01	26.44	< .001	***

Random effects						
Group	*N*	Slope	Variance	Correlation		
ID	94	(Intercept)	1.70			
		Imagine self	0.06	- .45		
		Distress	0.36	- .07	.42	
		Imagine self *Distress	0.00	.24	- .87	- .04
Residual	752		0.33			

Note. Random effects: ID (intercept), condition (slope), affective state (slope). AI = Autism Index.

*p < .05, **p < .01, ***p < .001

[12] The effect size was similar with the two non-significant predictors (AI and medication) excluded, R^2_M = .28, R^2_C = .88.

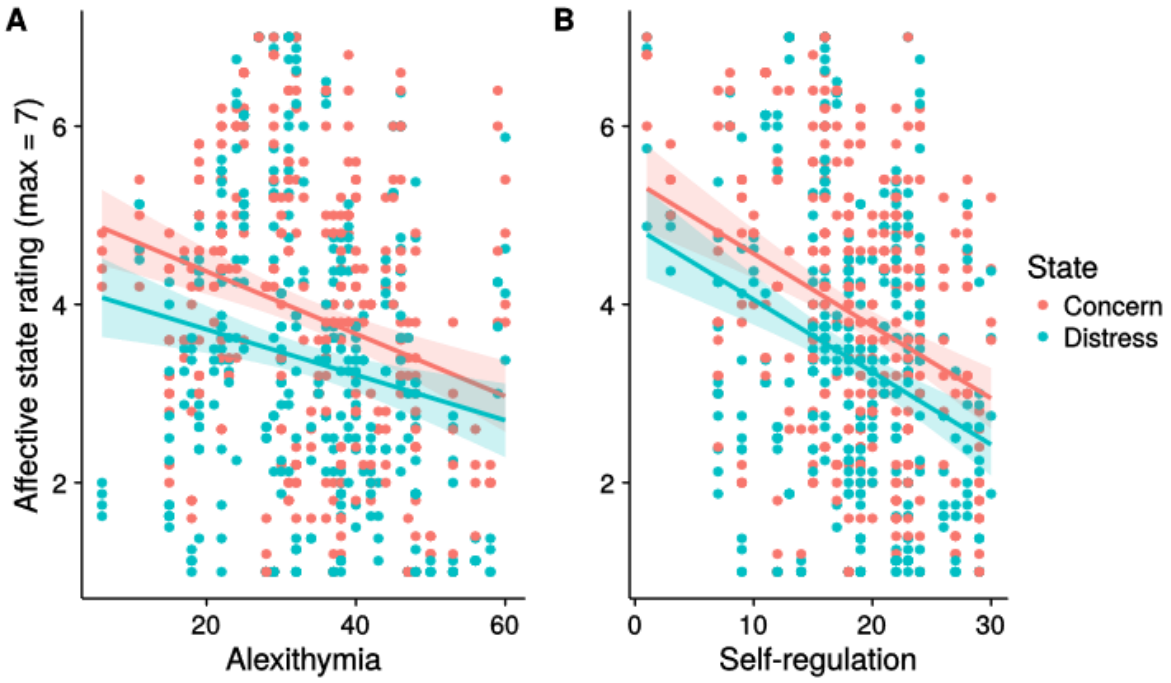

Figure 21. The influence of alexithymia (A) and self-regulation (B) on empathic concern and personal distress. Shaded areas indicate the 95% confidence intervals around the prediction.

Contrary to what was hypothesised, AI scores were negatively correlated with perceived pain intensity and unpleasantness (Hypothesis IV). Alexithymia partially mediated the relationship between autism traits and affective state: Neither empathic concern nor personal distress was correlated with AI scores once alexithymia was controlled for[13]. Thus, Hypothesis V was not upheld. Poorer self-regulation was associated with higher affective state ratings – both empathic concern and personal distress – and was not correlated with perceived pain (Hypothesis VIII). Contrary to Hypothesis IX, neither pain perception nor empathic concern was correlated with cognitive empathy.

[13] Recall that Study 1 showed that AI scores significantly predict alexithymia, $r = 0.55$, $R^2 = .30$, $F\ (1,95) = 41.31$, $p < .001$.

Muscle Reactivity

Are physiological indices of affective empathy and empathic concern correlated with amount of autism traits?

Hypothesis VI: Amount of autism traits will be positively correlated with muscle activity.

What other factors are associated with pain perception and empathic concern (versus personal distress)?

Hypothesis XI: Poorer self-regulation and cognitive empathy will be associated with increased muscle reactivity.

On average, muscle activity increased from about 500 ms after the start of the painful facial expression. Activity seemed to increase most and fastest in the M. orbicularis oculi region, the muscle involved in orbit tightening (Figure 22). However, standard deviations were large for muscle slope. Muscle activity was similar between perspective taking conditions. Table 26 shows the average muscle activity, relative to baseline, at the start of the painful facial expression (0 – 200 ms) and during the painful facial expression (1.4 – 3.4 s), as well as the change in muscle activity over time between 0 and 2.4 s (slope).

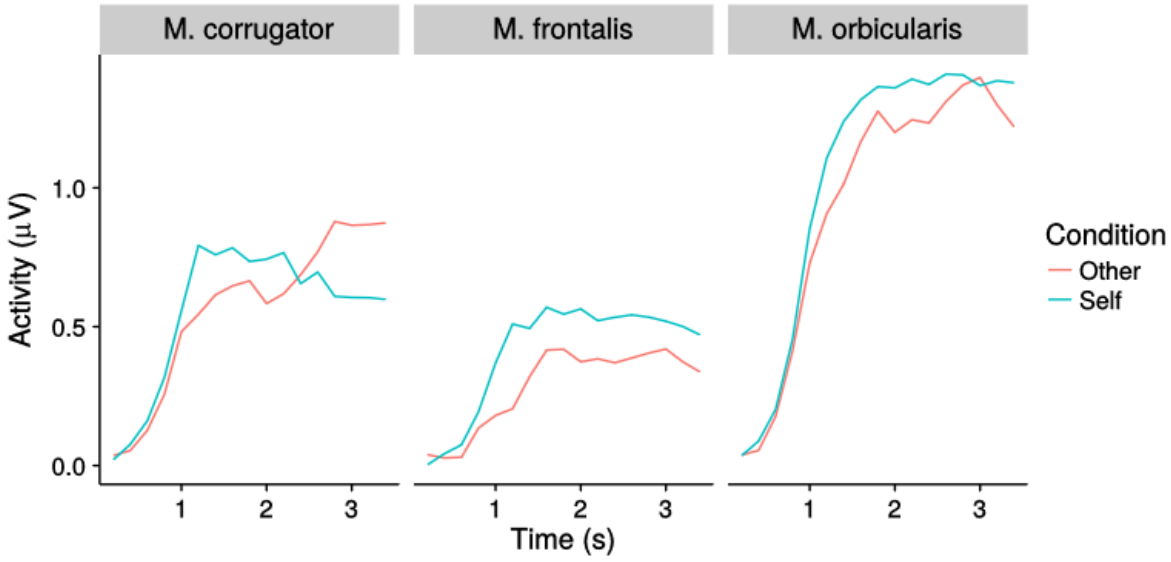

Figure 22. Activity in the M. corrugator supercilii, M. medial frontalis and M. orbicularis oculi regions from resting state to watching facial expressions of pain. Time 0 indicates the onset of the pain expression.

Table 26

Change in Muscle Activity and Muscle Slope During Facial Expressions of Pain

Muscle	Condition	Pain start		During pain		Slope	
		M	*SD*	*M*	*SD*	*M*	*SD*
M. corrugator	Other	0.04	0.58	0.75	2.06	0.83	11.61
	Self	0.02	0.48	0.68	2.08	- 0.58	9.12
M. orbicularis	Other	0.04	0.31	1.27	2.58	3.02	12.15
	Self	0.04	0.35	1.38	2.65	4.37	10.98
M. frontalis	Other	0.04	0.36	0.39	1.55	1.92	16.94
	Self	0.00	0.24	0.53	1.82	1.53	18.36

Note. Pain start: 0 – 200 ms; during pain: 1.4 – 3.4 s; slope: change in muscle activity over time between 0 – 2.4 s.

Average activity. Muscle amplitude data were positively skewed. Thus all models of muscle amplitude included a variance coefficient to model heterogeneity in the variance. A preliminary random effects analysis predicting muscle activity from the interaction between time (0 – 200 ms vs. 1.4 – 3.4 s), muscle, and condition was done to test whether the empathy-induction worked; in other words, whether muscle activity was higher during pain observation than during the start of the video. The model had a random intercept, with condition nested within muscle, nested within participant ID, and contained an exponential variance structure ($\delta = 1.95$).[14] The analysis showed a significant main effect for time (F [1, 576] = 91.93, $p < .001$) and a significant interaction between muscle and time, F [2,576] = 4.84, $p \leq .008$. Condition and its interactions were not significant (all ps > .2). On average, muscle activity was significantly higher while observing pain, $\boldsymbol{\beta} = 0.35$, $SE = 0.08$, t (576) = 4.12, $p < .001$. Specifically muscle activity during pain observation was higher in both the M. orbicularis oculi and M. corrugator supercilii muscles than in M. medial frontalis; $\boldsymbol{\beta} = 0.88$, $SE = 0.42$, t (576) = 2.08, $p \leq .038$, and $\boldsymbol{\beta} = 0.36$, $SE = 0.18$, t (576) = 2.06, $p \leq .040$, respectively. It should be noted that, though significant, the confidence interval of the coefficient estimate for M. corrugator supercilii during pain observation (i.e., for the Time *x* M. corrugator interaction) was close to zero (see Table 44, p. 384, and Figure 30, p. 385, in Appendix P). Thus, this significant result should be interpreted with some caution. The conclusion from the preliminary analysis is that the videos elicited significant muscle activity associated with expressions of pain.

Muscle type, medication, cycle, alexithymia, performance cognitive empathy, and AI scores were used to predict muscle activity during the painful facial expressions. To model the heterogeneous variance, a fixed variance structure that increased with AI was included in

[14] The model was originally specified with a maximal structure; in other words, with muscle, condition, and their interaction as random slopes and participant ID as random intercept, but this model did not converge after 10^7 iterations with the 'optim' optimiser.

the mixed-effects model. Both because there was no significant difference between the video conditions, and because models that included condition as a random intercept did not converge, the data were averaged within a cycle (i.e., over the different conditions) so that a simpler random structure could be used. To test whether AI scores are correlated with habituation rates, the interaction between AI and cycle was also added to the model. Participant ID, and muscle nested in participant ID, were used as the random intercepts, $\sigma^2_{ID} = 0.97$, $\sigma^2_{Muscle\ in\ ID} = 1.06$, $\sigma^2_{resid} = 0.86$. When alexithymia was not controlled for, muscle type and AI significantly predicted muscle activity (see Table 27). However, when alexithymia was entered into the model, with variance increasing linearly with alexithymia scores, AI was no longer significant and cycle was significant. In general, the M. orbicularis oculi response (*M* = 1.33, *SD* = 2.49) was significantly larger than the comparison response in M. medial frontalis (*M* = 0.99, *SD* = 2.67), but M. corrugator was not. Cycle 1 (*M* = 0.47, *SD* = 1.63) also elicited greater reactions than cycle 2 (*M* = 0.69, *SD* = 1.85). AI and alexithymia were both negatively correlated with muscle activity in the two different models. The model containing alexithymia predicted a higher amount of the marginal and the conditional variance in muscle activity, and had lower error variance. Figure 23 shows the relationship between AI, alexithymia and muscle activity. For comparison, a mixed-effects model using square-root transformed muscle amplitude as the outcome variable, and no variance structure, was also run. The model yielded similar results as the model reported above, and is given in Table 45, p. 386, in Appendix P.

Table 27

Mixed-Effects Models of Average Muscle Activity Relative to Baseline

Model	Fixed effects	β	*SE*	df_{effect}	df_{error}	*F*-value	Probability	
Model 1	M. corrugator	0.25	0.18	2	184	10.62	< .001	***
	M. orbicularis	0.82	0.18					
	Cycle	- 0.12	0.06	1	278	3.79	.053	.
	AI	- 0.33	0.13	1	91	6.05	.015	*
Model 2[a]	M. corrugator	0.25	0.19	2	184	10.63	< .001	***
	M. orbicularis	0.86	0.19					
	Cycle	- 0.33	0.09	1	278	13.45	< .001	***
	Alexithymia	- 0.26	0.13	1	91	4.04	.047	*

Note. Model 1*:* R^2_M = .07, R^2_C = .72; Model 2: R^2_M = .10, R^2_C = .99. Number of observations = 558, number of groups: ID = 93, muscle in ID = 279. AI = Autism Index.

[a] σ^2_{ID} = 1.00, $\sigma^2_{Muscle\ in\ ID}$ = 1.11, σ^2_{resid} = 0.02.

*p < .05, **p < .01, ***p < .001.

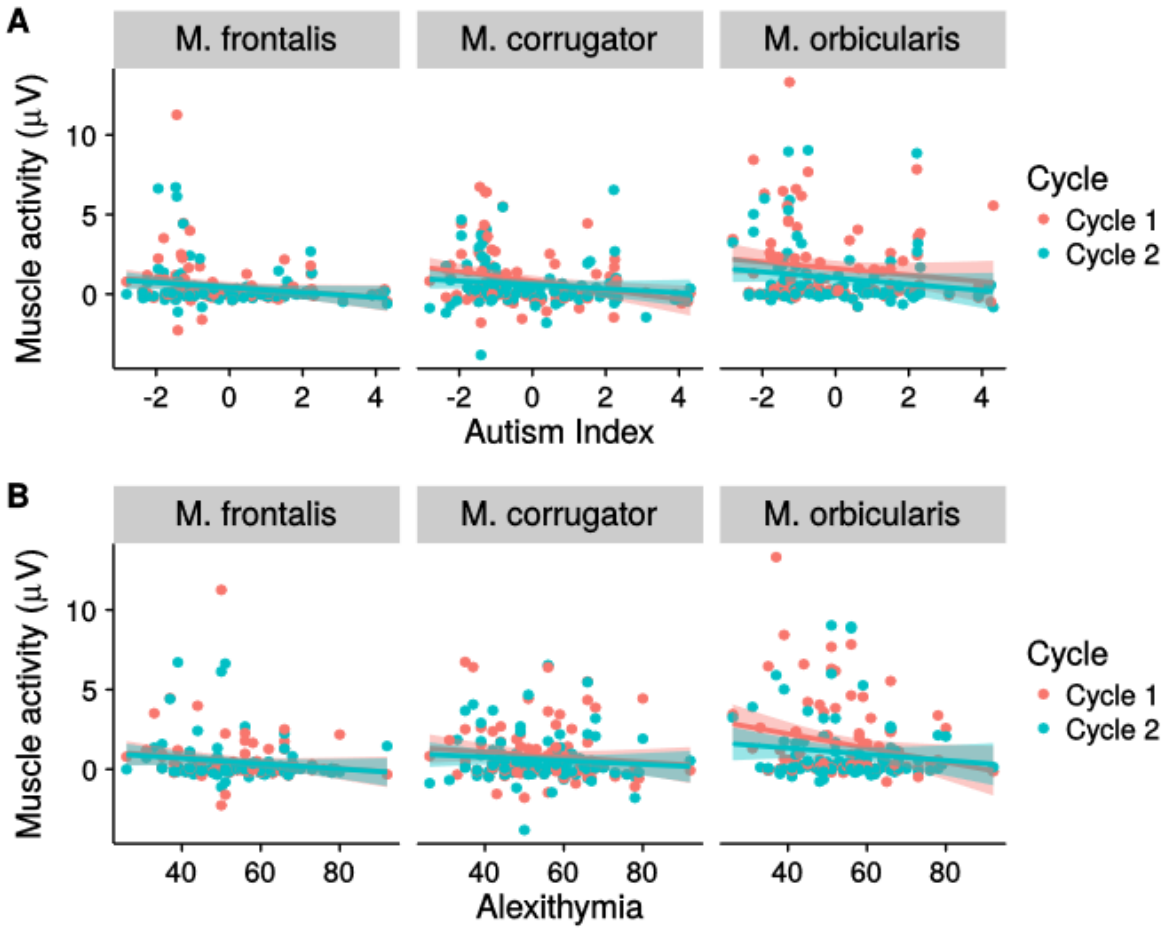

Figure 23. Predictors of muscle activity during facial expressions of pain. Muscle activity was greater in M. orbicularis oculi and during cycle 1. Two alternative models were proposed; one with Autism Index as a predictor (A), and one with alexithymia as predictor (B). Shaded areas denote 95% confidence intervals around the prediction.

Slope. To test the hypothesis that muscle reactivity is associated with autism traits, muscle slope was predicted from muscle type, medication, condition, cycle, alexithymia, performance cognitive empathy, self-regulation and AI. Only muscle significantly predicted slope, with M. orbicularis oculi having the steepest slope (M = 3.62, SD = 11.95). As the previous factors did not significantly predict muscle slope, an exploratory analysis was done using dispositional empathy rather than performance empathy: Muscle slope was predicted

from muscle type, trait affective empathy and trait cognitive empathy. As variance inflation factors were high and there were no differences between cycles or condition, the data were averaged over these points for optimal model fit[15]. The maximal random structure model did not converge, so a simpler random structure was used with participant ID as the random effect, $\sigma^2_{ID} = 3.87$, $\sigma^2_{resid} = 78.90$. Change in activity differed significantly between muscles, with M. corrugator supercilii associated with the smallest change in slope. There was no difference in slope between M. orbicularis oculi and M. medial frontalis. There was a statistically significant interaction between muscle type, affective empathy and cognitive empathy (see Table 28 and Figure 24). However, this was mainly driven by activity in the control muscle, M. medial frontalis. In M. medial frontalis, muscle slope was positively correlated with trait affective empathy in those with low cognitive empathy, but negatively correlated with trait affective empathy in those with high cognitive empathy. In M. corrugator supercilii there was little difference in slopes by either affective or cognitive empathy. The interaction between affective empathy and cognitive empathy was not significant in M. orbicularis oculi.

[15] Appendix P, Table 45, p. 302, shows the original model without averages over cycle or condition.

Table 28

Random-Effects Model of Change in EMG Activity Over Time (Muscle Slope)

Fixed effects	*SS*	*MS*	df_{effect}	df_{error}	*F*-value	Probability	
Muscle	669.67	334.83	2	182.14	4.24	.016	*
Affective empathy (T)	32.42	32.42	1	90.96	0.41	.523	
Cognitive empathy (T)	1.40	1.40	1	91.10	0.02	.894	
Muscle*Affective (T)	292.73	146.37	2	181.57	1.86	.159	
Muscle*Cognitive (T)	353.01	176.51	2	181.70	2.24	.110	
Affective*Cognitive (T)	293.28	293.28	1	91.14	3.72	.057	.
Muscle*Affective (T)*Cognitive (T)	651.82	325.91	2	181.74	4.13	.018	*

Fixed effects	**β**	*SE*	*df*	*t*-value	Probability	
M. corrugator	- 3.99	1.53	182.46	- 2.60	.010	*
M. orbicularis	- 0.24	1.53	181.51	- 0.16	.875	
Affective empathy (T)	- 1.96	1.14	270.83	- 1.72	.087	
Cognitive empathy (T)	0.24	1.16	270.83	0.21	.837	
M. corrugator *Affective (T)	1.53	1.58	181.60	0.97	.334	
M. orbicularis*Affective (T)	3.03	1.57	181.51	1.93	.056	
M. corrugator *Cognitive (T)	1.47	1.60	181.80	0.92	.360	
M. orbicularis*Cognitive (T)	- 1.91	1.60	181.51	- 1.19	.235	
Affective (T)*Cognitive (T)	- 3.58	1.05	270.83	- 3.42	.001	**
M. corrugator *Affective*Cognitive (T)	3.92	1.45	181.86	2.71	.007	**
M. orbicularis*Affective*Cognitive (T)	3.15	1.45	181.51	2.18	.031	

Note. R^2_M = .09, R^2_C = .13. Affective (T) = trait affective empathy; cognitive (T) = trait cognitive empathy. Number of observations = 284, number of groups (ID) = 95.

*p < .05, **p < .01, ***p < .001.

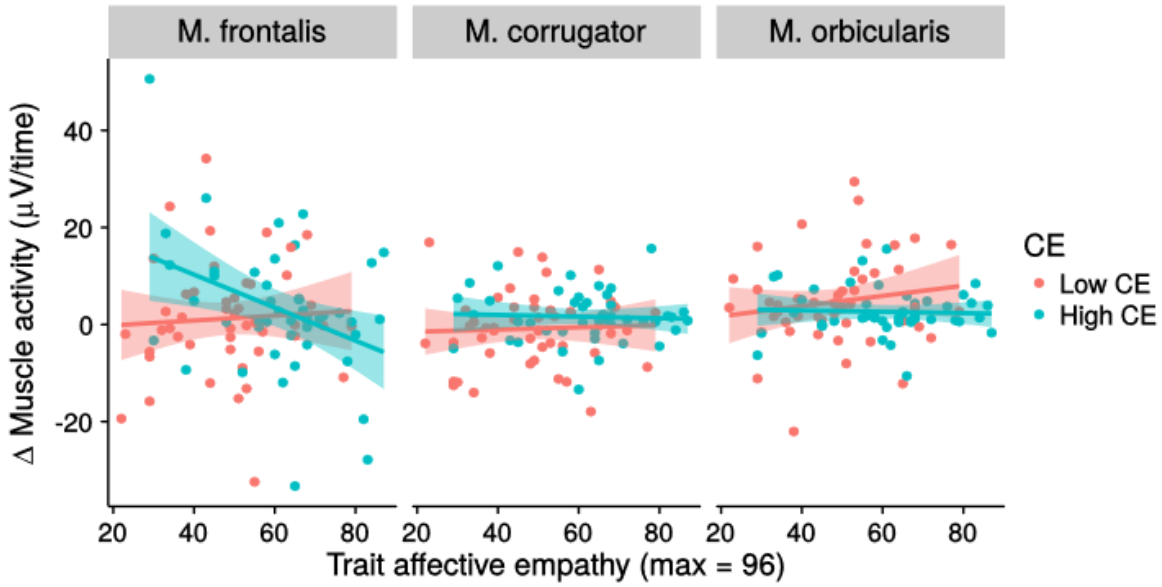

Figure 24. Predictors of muscle slope. Low and high trait cognitive empathy (CE) levels are represented as those falling below or above the median score. Shaded areas denote 95% confidence intervals around the prediction.

To conclude, the results of the analyses show that muscle reactivity increased when observing facial expressions of pain, and that both change in muscle amplitude from baseline and muscle slope were greater in M. orbicularis oculi than in M. medial frontalis (the control muscle). However, M. corrugator supercilii activity, the muscle responsible for contracting the brows, was not significantly greater than M. medial frontalis activity. Furthermore, the different perspective-taking conditions did not lead to differences in muscle activity. Contrary to the hypothesis, AI scores were not correlated with muscle amplitude or slope once alexithymia was controlled for (Hypothesis VI). Additionally, neither trait self-regulation nor performance cognitive empathy was associated with greater muscle activity (Hypothesis XI). However, the combination of high trait affective and trait cognitive empathy was associated with greater M. medial frontalis slope.

Resting State Autonomic Arousal, Empathy and Autism

Is there evidence of resting state autonomic dysregulation in participants with greater autism traits? Is resting state autonomic activity associated with empathy?

Hypothesis III: Higher resting state parasympathetic arousal (vagal cardiac control) will be associated with higher trait affective empathy and self-regulation scores.

Hypothesis X: Higher resting state parasympathetic arousal (vagal cardiac control) will be associated with increased state empathic concern, whereas higher resting state sympathetic arousal will be associated with increased personal distress.

Participants' resting state autonomic arousal values were within the normal range. The descriptive statistics and correlations with empathy are presented in Table 29. Regarding sympathetic arousal, resting state pre-ejection period and SCL were not correlated, r (80) = - .08, $p \leq .449$. Thus these scores were not aggregated to a sympathetic arousal variable. Regarding cardiac parasympathetic arousal, or cardiac vagal control, respiration was significantly correlated with RSA and tidal volume. Thus, RSA was predicted from respiration rate and tidal volume. The residuals of that regression were used as a respiration-independent indicator of resting state vagal cardiac control.

Table 29

Correlations Between Resting State Autonomic Arousal and Empathy Measures

	1	2	3	4	5	6	7	8	9	10	11	12	13
1. HR													
2. PEP	- .22												
3. RSA	- .42***	.03											
4. RR	.08	- .08	- .31**										
5. TV	.06	.15	.07	- .31**									
6. VC	- .11	- .04	.51**	- .11	- .01								
7. SCL	.02	- .09	.06	.06	- .17	.04							
8. AI	.21	- .10	- .08	.10	.08	.01	.11						
9. AE	.09	- .02	.09	- .15	.20	.09	- .19	- .29***					
10. TCE	- .01	.08	.07	- .21	.14	- .03	- .18	- .54***	.59***				
11. PCE	.02	.08	.02	- .12	- .09	- .03	.20	- .47***	.20	.25*			
12. SR	- .02	.00	- .04	- .05	- .02	.09	- .02	- .25*	- .39***	.01	.07		
13. Concern	.10	.08	- .04	- .05	.04	.03	- .15	- .23*	.55***	.39***	.20	- .27*	
14. Distress	.01	.09	.06	.00	- .03	.00	- .08	- .16	.48***	.35***	.18	- .32**	.89***

HR (bpm)		PEP (ms)		RSA (ms)		RR (bpm)		TV (mΩ/s)		VC		SCL (µS)	
M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
73.62	12.30	113.58	20.98	78.17	52.66	16.68	2.48	76.47	50.17	-2.39	16.83	4.61	2.33

Note. HR = heart rate; PEP = pre-ejection period; RSA = respiratory sinus arrhythmia; RR = respiration rate; TV = tidal volume; VC = vagal cardiac control; SCL = skin conductance level; AI = Autism Index; AE = affective empathy; TCE = trait cognitive empathy; PCE = performance cognitive empathy; SR = self-regulation; Concern = empathic concern; Distress = personal distress.

*p < .05, **p < .01, ***p < .001.

Resting state vagal cardiac control, pre-ejection period, heart rate and the interaction between the pre-ejection period and cardiac vagal control were used to predict AI and the different facets of empathy in separate linear regression models. To predict affective state, the interaction between state type (empathic concern versus personal distress), cardiac vagal control and pre-ejection period was also included in the model. As affective state ratings were repeated, a random-effects model was used with participant ID as the random intercept ($\hat{\sigma}^2_{ID}$ = 2.03, $\hat{\sigma}^2_{resid}$ = 0.29).

Resting state vagal cardiac control, pre-ejection period, and their interaction did not predict AI scores (see Table 30). AI was positively correlated with heart rate, β = 0.44, *SE* = 0.18, *t* (88) = 2.49, *p* = .016. When participants on antidepressants were excluded, heart rate was no longer positively correlated with AI, β = 0.28, *SE* = 0.18, *t* (81) = 1.62, $p \leq .109$. The autonomic variables did not significantly predict trait affective empathy (R^2_{adj} = 0, *F* [4, 86] = 0.39, $p \leq .812$), affective state (both empathic concern and personal distress; R^2_M = .04, R^2_C = .88), or trait or performance cognitive empathy (R^2_{adj} = 0, *F* [4, 86] = 0.18, $p \leq .949$, and R^2_{adj} = 0, *F* [4, 78] = 0.12, $p \leq .973$, respectively). Neither did they predict trait self-regulation, R^2_{adj} = 0, *F* [4, 86] = 0.52, $p \leq .725$.

Table 30

Linear Regression Results of Resting State Autonomic Arousal and Autism and Empathy Traits

Fixed effects	β	*SE*	df_{error}	*SS*	*MS*	*F*-value	Probability	
AI[a]								
Vagal control	0.01	0.18		0.02	0.02	0.01	.932	
PEP	0.04	0.19		0.14	0.14	0.05	.824	
HR	0.44	0.18		16.82	16.82	6.00	.016	*
Vagal control * PEP	0.21	0.18		3.68	3.68	1.31	.255	
Residuals			88	246.80	2.80			
Affective empathy (T)								
Vagal control	1.74	1.68		262.22	262.22	1.05	.308	
PEP	- 0.36	1.76		27.35	27.35	0.11	.742	
HR	1.07	1.69		99.78	99.78	0.40	.529	
Vagal control * PEP	0.23	1.72		4.51	4.51	0.02	.893	
Residuals			86	21477.97	249.74			
Affective state[b]								
State[c]	0.48	0.08	88	10.39	10.39	35.38	< .001	***
Vagal control	0.15	0.17	87	0.23	0.23	0.77	.382	
PEP	0.01	0.16	87	0.00	0.00	0.01	.908	
HR	0.14	0.16	87	0.25	0.25	0.84	.362	
State * Vagal control	- 0.01	0.08	88	0.01	0.01	0.02	.893	
State * PEP	0.02	0.08	88	0.03	0.03	0.10	.757	
Vagal control * PEP	- 0.04	0.16	87	0.03	0.03	0.10	.756	
State * Vagal control * PEP	- 0.01	0.08	88	0.01	0.01	0.02	.880	
Cognitive empathy (T)								
Vagal control	- 0.10	0.57		1.53	1.53	0.05	.815	
PEP	0.20	0.60		4.55	4.55	0.16	.687	
HR	- 0.27	0.57		6.09	6.09	0.22	.642	
Vagal control * PEP	- 0.31	0.59		7.86	7.86	0.28	.597	
Residuals			86	2402.40	27.93			

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Table 30 (cont.)

Cognitive empathy (P)							
Vagal control	- 0.01	0.09		0.04	0.04	0.05	.821
PEP	0.06	0.10		0.30	0.30	0.43	.515
HR	0.00	0.09		0.00	0.00	0.00	.980
Vagal control * PEP	0.01	0.09		0.01	0.01	0.02	.899
Residuals			78	54.66	0.70		
Self-regulation							
Vagal control	0.70	0.62		39.00	39.00	1.15	.287
PEP	- 0.20	0.65		4.37	4.37	0.13	.721
HR	- 0.04	0.63		0.11	0.11	0.00	.955
Vagal control * PEP	- 0.56	0.63		26.70	26.70	0.78	.378
Residuals			86	2927.49	34.04		

Note. All models: $df_{effect} = 1$. AI = Autism Index; PEP = pre-ejection period; HR = heart rate; T = trait; P = performance.

[a] Uncorrected for medication use. [b] Mixed-effects model; number of observations = 184, number of groups (ID) = 92. Coefficients estimates are provided for the fixed effects. The model was fit with a random intercept for participant ID, $\sigma^2_{ID} = 2.03$, $\sigma^2_{resid} = 0.29$.

[c] Empathic concern versus personal distress (baseline).

*$p < .05$, **$p < .01$, ***$p < .001$.

In summary, the relatively 'pure' resting state measures of sympathetic (pre-ejection period, SCL) and parasympathetic (vagal cardiac control) arousal were not correlated with AI scores. Heart rate was significantly positively correlated with AI, but no longer predicted AI when participants on antidepressants were excluded. Similar to Study 1, and contrary to hypotheses, resting state parasympathetic arousal (vagal cardiac control) was not associated with trait affective empathy, trait or performance cognitive empathy or trait self-regulation (Hypothesis III). Neither was resting state autonomic arousal (parasympathetic or

sympathetic) associated with subjective affective states to facial expressions of pain (neither empathic concern nor personal distress; Hypothesis X).

Autonomic Responses to Stimuli

Are physiological indices of affective empathy and empathic concern correlated with amount of autism traits?

Hypothesis VII: Amount of autism traits should be positively correlated with sympathetic reactivity and/or negatively correlated with parasympathetic reactivity, resulting in over-arousal.

What other factors are associated with pain perception and empathic concern (versus personal distress)?

Hypothesis XII: Increased empathic concern and better self-regulation will be associated with increased parasympathetic reactivity and potentially increased sympathetic reactivity (co-activation).

Averaging across all blocks, physiological changes to the conditions were small compared to resting state values and the variance in responses (see Table 31). SCL showed the most consistent change from resting state.

Table 31

Autonomic Changes to Viewing Painful Expressions

Condition	PEP		RSA		Vagal cardiac control		SCL		HR	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Baseline	113.58	20.98	78.17	52.66	- 2.39	16.83	4.61	2.33	73.62	12.30
Other	113.18	21.04	75.34	48.90	- 0.14	17.12	4.88	2.52	73.28	12.01
Self	112.90	20.17	76.97	50.49	1.35	15.26	4.90	2.49	73.08	11.83
	Δ PEP		Δ RSA		Δ Vagal cardiac control		Δ SCL		Δ HR	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Other	- 0.19	4.83	- 2.83	30.59	2.26	27.29	0.45	0.72	- 0.23	2.77
Self	- 0.47	4.77	1.20	29.38	3.74	24.60	0.47	0.71	- 0.44	3.10

Note. PEP = pre-ejection period; RSA = respiratory sinus arrhythmia, SCL = skin conductance level; HR = heart rate.

Preliminary random-effects analyses were run to test whether facial expressions of pain elicited changes in autonomic arousal (pre-ejection period, vagal cardiac control, SCL, heart rate) or respiration from baseline. When the data were aggregated by condition, there were no significant differences from baseline except for SCL, F (2, 166) = 39.54, $p < .001$, $R^2_M = .009$. However, arousal was significantly predicted from video block order (four blocks in total) for each of the autonomic arousal measures: Both heart rate and pre-ejection period decreased significantly from baseline to the first block of pain videos and significantly increased again after block 1 so that arousal in subsequent blocks was not significantly

different from baseline. In contrast, vagal control increased from baseline to block 1, and then marginally (but not significantly) decreased for the next three blocks, so that these blocks were not significantly different from baseline. SCL was increased from baseline for all blocks, though block 1 elicited significantly higher responses than subsequent blocks (see Table 32). For all the models except cardiac vagal control, interindividual variance was high compared to variance between blocks. Residuals of the analyses are shown in Table 47, p. 388, in Appendix P. Overall, the data suggest co-activation of the parasympathetic and sympathetic systems in response to the first block of videos, with a steady return to resting state values during the subsequent blocks. Respiration rate was significantly increased from rest for all the pain stimuli, emphasising the need to statistically control for the influence of respiration rate and tidal volume on RSA. Consequently, I analyse and discuss cardiac vagal control rather than RSA in all further analyses.

Table 32

Changes in Autonomic Arousal and Respiration Rate Across Experimental Blocks

Model	*df*	*F*	*p*	R^2_M	Differences [a]
PEP	4, 366	7.33	< .001	.002	Base > Block 1, Block 1 < Blocks 2 - 4
Vagal control	4, 374	3.27	.012	.027	Base < Block 1
SCL	4, 330	26.47	< .001	.008	Base < Blocks 1 -4, Block 1 > Blocks 3 - 4
HR	4, 374	11.66	< .001	.003	Base > Block 1, Block 1 < Blocks 2 - 4
Respiration	4, 374	9.32	< .001	.019	Base < Blocks 1 - 4

Note. Fixed effect: Time. PEP = pre-ejection period; SCL = skin conductance level; HR = heart rate; base = 2-minute baseline.

[a] *p*s < .005.

To test whether AI, empathic concern and trait self-regulation were associated with autonomic responses to facial expressions of pain, four different linear mixed-effects models were run predicting the pre-ejection period, vagal cardiac control, SCL, and heart rate. Physiological arousal was predicted from medication use, video cycle (with two blocks, one of each condition, within a cycle), condition, AI scores, empathic concern and self-regulation. To test whether habituation rates were correlated with AI scores, the interactions between condition, AI and cycle were also added to the model. Participant ID was entered as a random intercept and condition as a random slope in the starting models. For cardiac vagal control and SCL, there was little variance within condition, thus the data were aggregated within cycles within a participant, and condition was not included in the model (see Appendix P, Table 48, p. 389, for models with condition). There were no differences in the results between the maximal and simplified models. Because of the general pattern in habituation from block 1 to block 2 within cycle 1, the models were also run using block order (1- 4) instead of cycle (1 – 2) as a predictor. As there were no differences between these models and the models using cycle, they are not included in the results. The final models, which include only significant predictors, are presented in Table 33.

Table 33

Linear Mixed-Effects Models of Autonomic Arousal to Pain Observation

Fixed effects	β	*SE*	*SS*	*MS*	df_{effect}	df_{error}	*F*-value	Probability	
PEP									
Base PEP	19.37	0.39	24257.88	24257.88	1	90.98	2473.77	< .001	***
Cycle	0.86	0.23	136.01	136.01	1	276.89	13.87	< .001	***
Vagal control[a]									
Base vagal control	- 3.83	0.67	2759.90	2759.90	1	184	32.75	< .001	***
AI	- 0.14	0.67	3.69	3.69	1	184	0.04	0.834	
Cycle	- 2.34	0.94	518.69	518.69	1	184	6.16	0.014	*
AI*Cycle	1.92	0.95	347.20	347.20	1	184	4.12	0.044	*
SCL									
Base SCL	2.39	0.07	131.07	131.07	1	81.00	1099.33	< .001	***
AI	0.02	0.07	0.01	0.01	1	81.93	0.08	.775	
Cycle	- 0.13	0.04	1.32	1.32	1	81.36	11.08	.001	**
AI*Cycle	- 0.08	0.04	0.53	0.53	1	82.26	4.44	.038	*
HR									
Base HR	11.53	0.24	9025.94	9025.94	1	92.21	2396.88	< .001	***
Cycle	0.80	0.14	117.95	117.95	1	281.98	31.32	< .001	***
AI	- 0.07	0.24	0.32	0.32	1	93.53	0.09	.770	
AI*Cycle	- 0.38	0.14	26.61	26.61	1	285.33	7.07	.008	**

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Table 33 (cont.)

	Random effects				
Analysis	Group	*N*	Slope	Variance	Correlation
PEP	ID	93	(Intercept)	12.69	
			Condition	0.08	-1
	Residual	370		9.81	
Vagal control	ID	95	(Intercept)	0.00	
	Residual	189		84.26	
SCL	ID	84	(Intercept)	0.36	
	Residual	164		0.12	
HR	ID	95	(Intercept)	3.48	
			Condition	0.10	1
	Residual	378		3.77	

Note. Random effects: ID (intercept). PEP: R^2_M = .95, R^2_C = .98; Vagal cardiac control: R^2_M = .17, R^2_C = .17; SCL: R^2_M = .92, R^2_C = .98; HR: R^2_M = .94, R^2_C = .97. PEP = pre-ejection period; SCL = skin conductance level; HR = heart rate; AI = Autism Index.

*p < .05, **p < .01, ***p < .001.

In each of the analyses, physiological arousal at resting state significantly predicted arousal during pain observation. Corresponding with the preliminary analyses, once resting state arousal was controlled, video cycle had a significant effect on all indices: On average, pre-ejection period increased during the second cycle of videos, regardless of the participant's amount of autism traits. Vagal cardiac control, heart rate and SCL, on the other hand, showed significant interactions between AI scores and cycle: Participants with low AI scores showed greater decreases in cardiac vagal control from cycle 1 to cycle 2, indicating greater decreases in parasympathetic arousal (see Figure 25). Dependent *t*-tests comparing

cardiac vagal control between cycles confirmed that there was a significant decrease in cardiac vagal control from cycle 1 to cycle 2 in the low AI group, $M_D = 4.32$, $t\,(31) = 1.87$, $p = .035$, $d = .35$, but not in the high AI group, $M_D = 0.37$, $t\,(28) = 0.17$, $p \leq .434$, $d = .04$. The groups did not differ in cardiac vagal control during cycle 1, $t\,(51) = 1.02$, $p \leq .312$, $d = .26$.

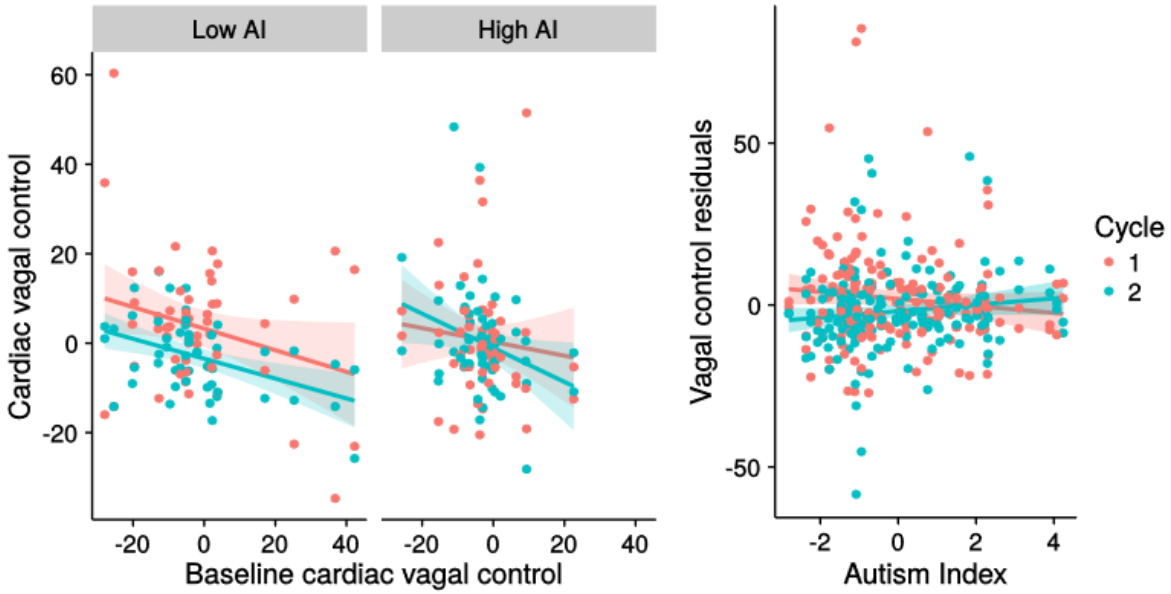

Figure 25. Cardiac vagal control showed greater changes in participants with low Autism Index (AI) scores. To better see the interaction between cycle and AI, cardiac vagal control during pain perception was predicting from resting state vagal cardiac control, and the residuals of that analysis (corresponding to changes from resting state) are depicted in plot B. The low and high AI groups represent the first and third tertiles, respectively. Shaded areas indicate 95% confidence intervals around the prediction.

Corresponding to the evidence of decreasing parasympathetic arousal, there was a greater increase in heart rate from cycle 1 to cycle 2 in participants with low AI scores compared to those with high AI scores (see Figure 26). In contrast, participants with high AI scores showed greater sympathetic changes: SCL was higher during cycle 1 for these participants than for participants with low AI scores, and then decreased to cycle 2 (see Figure 27). The significant interactions were explored further with independent *t*-tests comparing cycle 1 arousal in the low and high autism trait groups: Participants in the high AI group had significantly higher heart rates (M_{High} = 77.67, SD_{High} = 11.61; M_{Low} = 69.88, SD_{Low} = 11.61; t [58] = 2.65, $p \leq .010$, d = .68) and SCL (M_{High} = 5.74, SD_{High} = 2.19; M_{Low} = 4.42, SD_{Low} = 2.33; t [52] = 2.17, $p \leq .034$, d = .59) than those in the low AI group.

These results correspond to heightened sympathetic arousal in cycle 1 and diminished reductions in parasympathetic arousal from cycle 1 to cycle 2 in participants with high AI scores. For descriptive statistics of the autonomic changes by cycle and AI group, see Appendix P, Table 49 and Table 50. Appendix P also shows individual changes in autonomic activity by block. Removing participants on antidepressants made no difference to the results of the models. Furthermore, empathic concern and self-regulation did not predict autonomic arousal while observing facial pain.

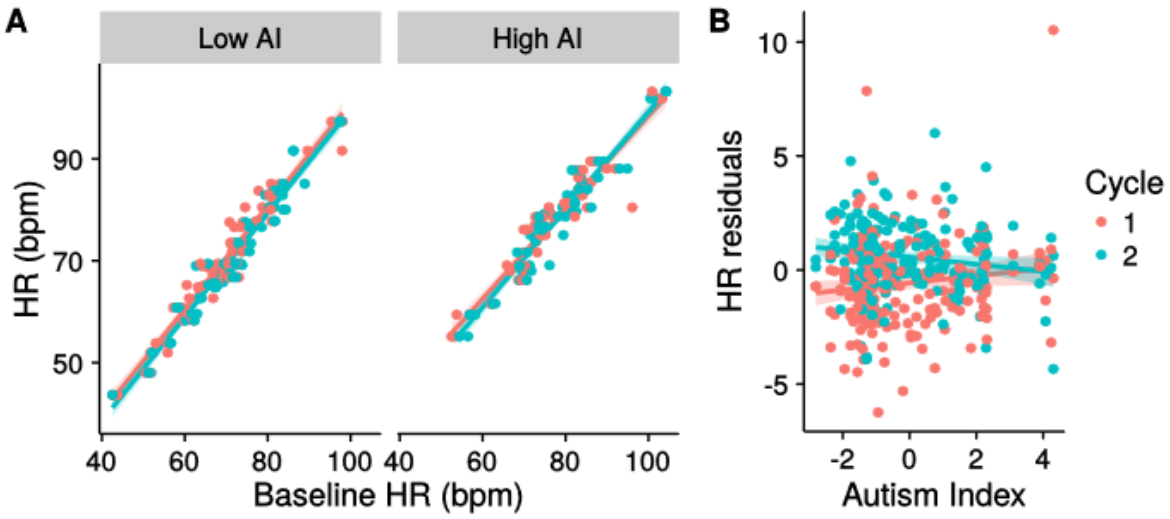

Figure 26. Heart rate (HR) responses to facial expressions of pain. Heart rate increased from cycle 1 to 2 in participants with low Autism Index (AI) scores, and remained the same in participants with high AI scores. To better see the interaction between cycle and AI, heart rate during pain perception was predicting from resting state heart rate, and the residuals of that analysis (corresponding to changes from resting state) are depicted in plot B. The low and high AI groups represent the first and third tertiles, respectively. Shaded areas indicate 95% confidence intervals around the prediction.

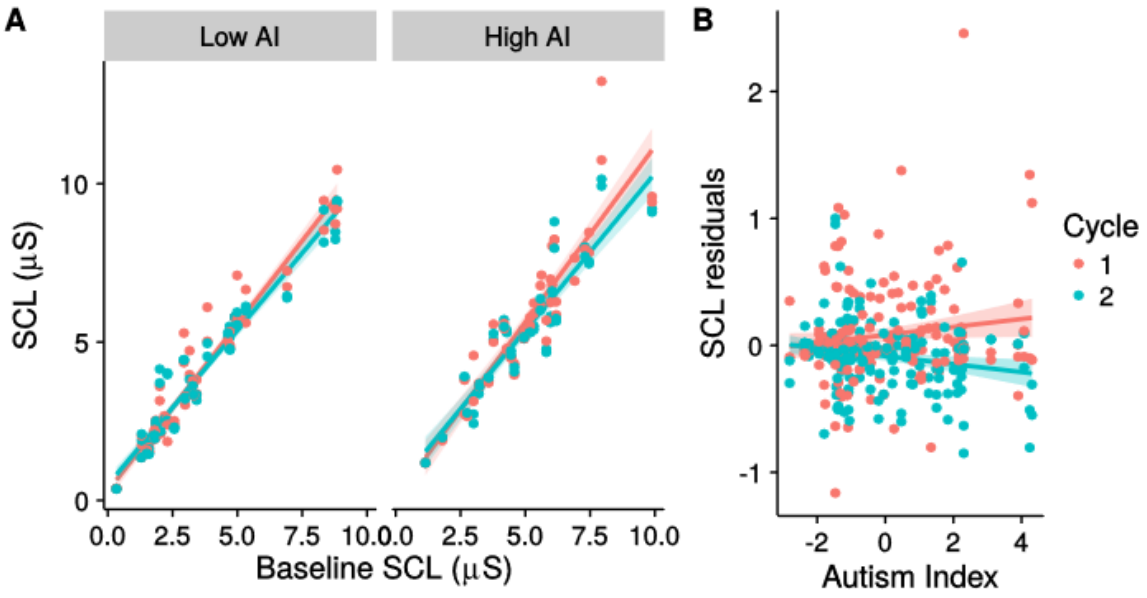

Figure 27. Skin conductance level (SCL) while observing facial expressions of pain. In participants with low Autism Index (AI) scores, SCL remained the same from cycle 1 to 2; whereas, in participants with high AI scores, SCL decreased. To better see the interaction between cycle and AI, SCL during pain perception was predicting from resting state SCL, and the residuals of that analysis (corresponding to changes from resting state) are depicted in plot B. The low and high AI groups represent the first and third tertiles, respectively. Shaded areas indicate 95% confidence intervals around the prediction.

To conclude, the videos elicited a significant autonomic response: The evidence suggests co-activation of the sympathetic and parasympathetic systems to the first cycle of pain videos, followed by a decrease in arousal in both systems. AI score was not significantly related to physiological changes on its own; however, there was a significant interaction between AI and video cycle in vagal cardiac control, heart rate, and skin conductance. Participants with low AI scores exhibited a significant reduction in parasympathetic arousal from the initial heightened response in cycle 1, whereas participants with high AI scores did

not. Additionally, participants with high AI scores displayed a greater threat response marked by increased SCLs during the first cycle of videos, which subsequently significantly decreased during the second cycle of videos. This pattern of activity is consistent with the hypothesis of heightened distress (Hypothesis VII) and reduced flexibility of cardiac vagal control in participants with high amounts of autism traits. Contrary to what was hypothesised, neither empathic concern nor self-regulation was significantly correlated with physiological responses (Hypothesis XII**)**.

Discussion

Similar to Study 2, the aim of this study was to investigate whether subjective affective states and physiological responses (autonomic and muscular) were diminished, intact, or heightened in participants with varying amounts of autism traits. In this study, participants did not see the sensory application of pain; only facial affective responses to the implied pain. Participants were told that the patients in the videos (who were actually actors) were undergoing painful medical treatment. The responses elicited in this study thus represent a response to more complex empathy-inducing stimuli than those presented in Chapter 6. First, facial expressions of pain are less salient than stimuli featuring sensory application of pain. For example, Vachon-Presseau et al. (2011) found that the nociceptive muscle flexion reflex was significantly less in response to seeing facial expressions of pain as opposed to seeing physical pain being inflicted. Second, individuals higher in autism traits find it significantly more difficult to identify facial expressions, as was shown in Study 1. Therefore, although affective responses to observed physical pain were not found to be correlated with autism traits in Study 2, less salient and more complex stimuli that require

greater cognitive empathy – both in terms of emotion recognition and in terms of being able to take the perspective of the other person (seeing that the infliction of pain is never directly observed) - may reveal subtle differences in empathy for pain in individuals with more autism traits. Alexithymia was controlled for in these analyses because Bird and colleagues (2010) have argued that it is specifically alexithymia, and not autism, that leads to reduced affective and cognitive empathy in people with ASD. Furthermore, a previous study has shown that alexithymia can impair emotion recognition, which may have affected empathic concern for the target when only seeing their facial expression (Cook et al., 2013).

As participants with greater amounts of autism traits have poorer perspective taking skills, a second aim of this study was to investigate whether, if participants were specifically asked to take the perspective of the other person, this would benefit or hinder participants with more autism traits, and reflect in participants' physiological responses or subjective empathic concern. A third aim of the study was to investigate whether reduced self-regulation and cognitive empathy would be correlated with greater affective reactions and higher ratings of pain unpleasantness and intensity, as was found in Study 2. Lastly, Study 2 found no correlation between autism traits and cardiac autonomic measures in participants not taking antidepressants. This study aimed to replicate that finding. Participants' self-reported affective responses, their facial muscle reactivity while watching the facial expression of pain, their resting state arousal, and their sympathetic and parasympathetic responses while watching the facial expressions of pain are discussed in turn.

Self-Reported Affective State and Perceived Pain

Participants reported the unpleasantness and intensity of the pain and rated their affective state (i.e., empathic concern and personal distress) after each block of facial expressions. On average, participants reported low to moderate levels of empathic concern and personal distress to the videos, suggesting that the videos were effective in eliciting affective responses. Although empathic concern and personal distress were again correlated at each time point, participants reported significantly less personal distress than empathic concern to the videos.

Video cycle (first or second round of perspective-taking), medication use and amount of autism traits significantly predicted perceived pain ratings (both unpleasantness and intensity). In terms of habituation to the stimuli, not only did participants' perceived pain ratings not decrease over time, but their ratings actually increased from cycle 1 to cycle 2. This increasing pattern of responses to pain is similar to that seen in Reicherts et al. (2013), who suggested that pain perception may have a cumulative effect. However, a cumulative effect was not found within autonomic or muscle measurements in this study, which instead showed diminishing responses after each block. Furthermore, empathic concern and personal distress did not differ between cycles. I speculate that the autonomic orienting response seen during the first cycle may have heightened participants' subsequent awareness of the target's pain, without the need for further increases in physiological or subjective distress. Medication use was associated with significantly higher perceived pain. This result is similar to Study 2, where participants using medication also reported greater pain unpleasantness and intensity. Again, it is possible that medication use increased resting state stress-related arousal (as discussed in *Autonomic arousal*, pp. 161 and 224), thereby increasing orientation towards

potentially threatening stimuli and heightening pain perception. Whereas autism traits were not related to perceived pain in Study 2, autism traits were negatively correlated with perceived pain in this study. Perceived pain ratings were not correlated with alexithymia; similar to what was found in Bird and colleagues (2010) during observation of sensory pain. Previous studies investigating self-reported perceived pain in ASD have all used sensory pain stimuli, not facial expressions, and thus are not directly comparable. However, it is interesting that Bird and colleagues (2010) found no difference in perceived pain between ASD and alexithymic controls under high pain conditions, but found that participants with ASD rated the low pain conditions as significantly less unpleasant than their non-ASD counterparts. Thus, participants with high autism traits may be less sensitive to low-salience pain images. This conclusion is tentative, as medication use – which is positively correlated with ASD traits - was positively correlated with perceived pain. However, specific medications may have separable and converse effects from ASD. Unfortunately, there were not enough participants in the different medication groups to be able to tease apart the effects of different medications on pain perception.

Affective states (both empathic concern and personal distress) were predicted by medication use, amount of autism traits and self-regulation. However, once alexithymia was controlled for, neither autism traits nor medication use significantly predicted affective states. These results concur with that of Bird and colleagues (2010), who found that affective empathy was intact in ASD once alexithymia was accounted for. As in their study, participants with higher levels of alexithymia reported lower affective state ratings. Affective state ratings were also negatively correlated with self-regulation ability, as was the case in Study 2. In other words, poor self-regulation was associated with heightened empathic

concern and personal distress. Unlike Study 2, poorer self-regulation was not correlated with the perceived unpleasantness or intensity of the pain. These results support the view that participants with poor self-regulation have poor control over their affective reactions, even when they do not perceive the pain as more intense than good regulators do. Again, it was expected that the correlations between self-regulation and empathic concern, and self-regulation and personal distress, would be in opposite directions – with good self-regulation predicting high levels of empathic concern but low levels of distress. However, no interaction effect was found. As before, the high correlation between the empathic concern and personal distress responses may have prevented separable effects from being evident. In this case, though poor self-regulators report higher empathic concern, these high ratings may not be beneficial for prosocial behaviour. Further studies on the association between empathic concern and prosocial behaviour in poor self-regulators are needed to test this proposition. For example, in addition to measuring self-reported empathic concern, experimenters can test prosocial behaviour using a resource allocation (Decety et al., 2015) or helping task (Malcolm-Smith, Woolley, & Ward, 2015). In this way, a possible moderating effect between self-regulation, empathic concern and prosocial behaviour can be tested.

The correlations between self-regulation, alexithymia and empathic concern may explain diverging correlations between autism and affective empathy in previous studies: High amounts of autism traits *per se* may not be correlated with empathy, but individuals with ASD who have poor self-regulation may show heightened affective responses (as predicted by the empathy imbalance hypothesis), whereas individuals with ASD who have alexithymia may show reduced responses (as predicted by the global empathy deficit hypothesis).

I expected that cognitive empathy would be required to interpret the facial expressions, and thus that performance cognitive empathy would be correlated with pain perception and empathic concern. However, neither pain perception nor empathic concern was correlated with performance cognitive empathy. These results are similar to those of Study 2. Related to cognitive empathy ability, I investigated whether deliberate perspective taking would influence pain perception and affective states. Perspective, in other words imagining the other's pain versus imagining how you would feel if experiencing the pain, did not significantly affect pain intensity ratings; a finding similar to that of previous studies (Lamm et al., 2007, 2008). In contrast to what was predicted, perspective also did not predict affective response. Batson and colleagues (1989, 1991, 1997) have argued that imagining how you would feel in a situation, versus imaging how someone else would feel, leads to different emotional sequelae. Subsequent studies (Batson et al., 1997; Lamm et al., 2007) found that self-perspective ("imagine self") conditions lead to greater feelings of personal distress, whereas the other-perspective ("imagine other") conditions lead to greater feelings of empathic concern. In this study there was no interaction between type of affective state and perspective. This finding may be explained by the fact that empathic concern and personal distress ratings were highly correlated. As in Study 2, the evidence suggests that these questions may share an underlying unitary construct. Most importantly for this study, deliberately taking a specific perspective did not interact with autism traits to predict affective state. This result concurs with the results above, suggesting that complex cognitive empathy, specifically perspective taking, is not necessary to feel an affective empathic response to perceiving another's pain. It also resonates with the animal empathy literature,

which shows that basic affective empathy and caring behaviour does not require complex cognitive empathy (Bartal et al., 2011; Custance & Mayer, 2012).

In summary, perceived pain increased over time for all participants. Alexithymia was correlated with reduced empathic concern for others' distress, which may explain reports of reduced empathic concern in ASD. Amount of autism traits was negatively correlated with perceived pain, but was not correlated with affective state (both empathic concern and personal distress) once alexithymia was controlled for. Medication use was associated with increased intensity and unpleasantness of pain perception. In contrast, poorer self-regulation was associated with higher subjective affective states to the perceived pain, but was not correlated with the perceived unpleasantness or intensity of the pain. These findings provide explanations for previous results of alternatively diminished or heightened affective arousal in ASD, and suggest that alexithymia and self-regulation ability, rather than autism, may drive differences in affective empathy. The findings pave the way for studies to explore the causal mechanisms of empathy. Lastly, cognitive empathy and perspective were not correlated with subjective affective states, suggesting that automatic affective responses to others' pain expressions do not require complex cognitive empathy.

Muscle Reactivity

Muscle response to observing facial expressions of pain. The pattern of elicited muscle activity shows that the empathy induction was successful. Activity in all three muscles, M. orbicularis oculi, M. corrugator supercilii and M. medial frontalis, increased significantly from the start of the video to the time of greatest pain display. As expected, muscle activity was greater in M. orbicularis oculi than in M. medial frontalis. M. orbicularis

oculi is responsible for forehead tightening and closing of the eyes, and has been found to be active when viewing facial grimaces or pain expressions (Lanzetta & Englis, 1989; Lepron et al., 2015; Vaughan & Lanzetta, 1980), as well as being the predominantly active muscle when experiencing first-hand pain (Kunz & Lautenbacher, 2014; Prkachin & Craig, 1995). In contrast, M. medial frontalis is responsible for lifting the brows and is associated more consistently with feelings of fear and surprise rather than pain or concern. These results confirm that participants experienced empathic muscular reactions to the facial expressions of pain. Similar to study 2, these results show muscle activation to pain observation; consistent with the hypothesis of muscle mimicry - and expression of concern for the injured party – rather than a freezing response when observing others' pain.

Contrary to what was expected, M. corrugator supercilii activity, the muscle responsible for pulling the brows inward and together in a frown, was not significantly different from M. medial frontalis activity. M. corrugator supercilii shows moderate activation to first-hand pain (Kunz & Lautenbacher, 2014) and to unpleasant pictures (Kaye, Bradford, & Curtin, 2016). However, muscle reactivity to unpleasant pictures may not be comparable to muscle reactivity to facial pain: Facial pain expressions elicit less strong responses than first-hand images of sensory pain; and the strongest reactions seem to occur when both the actual painful stimulus and the facial expression of pain are visible (Sun et al., 2015). In contrast to M. orbicularis activity, M. corrugator supercilii reactivity to painful expressions may occur in short bursts, if at all; rather than in a sustained way as is the case with M. orbicularis oculi activity (Lamm et al., 2008; Sun et al., 2015). Thus, sustained M. corrugator supercilii activity, as is most frequently measured in studies, may not be significantly different from neutral when observing facial expressions of pain (Sun et al.,

2015; though see González-Roldán, Muñoz, Cifre, Sitges, & Montoya, 2013). Thus, overall muscle reactivity was consistent with reactions of concern or pain.

Association between muscle reactivity and amount of autism traits. This study was the first to examine facial muscle mimicry to pain in individuals with ASD. I predicted that, once alexithymia is controlled, muscle reactivity would be uncorrelated with autism traits. Similar to the subjective affective state ratings, autism traits were negatively correlated with muscle amplitude while observing pain. However, once alexithymia was controlled for, autism traits were no longer correlated with muscle amplitude. These results are similar to that of Bird and colleagues (2010), who demonstrated that non-alexithymic individuals with ASD do not show deficits in affective empathy. Moreover, Bird and colleagues (2010) demonstrated that the relationship between alexithymia and affective empathy was the same in participants with and without ASD, thus refuting objections that the non-significant result between ASD and empathy was merely a statistical artefact caused by the shared variance between ASD and alexithymia. This study extends their work by showing that alexithymia is not only correlated with affective empathy at the neural level, but also at the muscular level. Specifically, alexithymia was negatively correlated with muscle amplitude to facial expressions of pain. The muscle amplitude results also correspond to participants' subjective affective responses discussed above. In other words, alexithymia was negatively correlated with both subjective affective states and muscle reactivity to perceived pain. Again, these results may explain previous conflicting findings regarding intact (Deschamps et al., 2015; Mathersul et al., 2013; Schulte-Rüther et al., 2010) or diminished (Beall, Moody, McIntosh, Hepburn, & Reed, 2008; McIntosh et al., 2006) muscle mimicry in ASD, as previous studies showing diminished muscle mimicry in ASD did not control for alexithymia.

Moving beyond the relationship between autism traits and the magnitude of muscle reactivity, I also investigated the possibility that muscle reactivity patterns – that is to say, change in activity over time - is correlated with autism traits, or that individuals with high amounts of autism traits would show different habituation patterns to perceiving facial pain than do individuals with low amounts of autism traits. Change in muscle response over time, in other words muscle slope, was not correlated with either amount of autism traits or alexithymia. Moreover, there was no interaction between amount of autism traits and video cycle, suggesting no differences in habituation between low and high autism trait participants. The combination of these results suggests that muscle mimicry of facial pain is unaffected in non-alexithymic individuals with high amounts of autism traits. This conclusion holds both for the magnitude and pattern of muscle responses.

Empathy, perspective taking and muscle reactivity. Participants with low trait affective empathy, who also had high trait cognitive empathy, had greater increases in muscle activity (i.e., greater changes in muscle activation) in the M. medial frontalis than participants with high trait affective empathy and low trait cognitive empathy. The significance of this result is unclear, but it could indicate that participants with low affective empathy and high cognitive empathy experienced more surprise – associated with lifting of the brow and hence M. medial frontalis activity - than concern for the targets. In contrast, participants with high affective empathy, but low cognitive empathy, exhibited greater changes in M. orbicularis activity, congruent with pain mimicry. Similar to the empathic concern ratings, these results suggest that trait affective empathy is more important for eliciting a congruent facial response to perceived pain than trait cognitive empathy is. In contrast with the correlation between trait empathy and muscle reactivity, neither self-reported affective state during the videos nor trait

self-regulation ability was associated with muscle activity. This result is similar to Study 2 and to the results of Reicherts and colleagues, who did not find any association between EMG activity and state anxiety (Reicherts et al., 2012, 2013).

Participants were asked in alternate blocks to either adopt the perspective of the other person by imaging how that person felt while experiencing the pain (imagine other), or to imagine how they would feel if they were experiencing the pain themselves (imagine self). It was hypothesised that whether muscle reactivity is inhibited or activated may depend, in part, on the ability to take the perspective of the other person. Specifically, it was hypothesised that taking a self-perspective would activate greater defensive muscle activation (as found in Lamm et al., 2008), whereas taking the perspective of the other would either reduce muscle reactivity (Avenanti et al., 2005; Avenanti, Minio-Paluello, Sforza, et al., 2009) or not lead to muscle activation [16]. Furthermore, I hypothesised that participants high in autism traits would show reduced changes in muscle activity in the imagine-other condition compared to low autism trait individuals (as they may find it difficult to take the perspective of the target), and heightened muscle reactivity in the imagine-self condition due to reduced self-regulation and increased personal distress.

Lamm and colleagues (2008) found that M. orbicularis oculi activity to observed pain was heightened only in the imagine-self condition, not the imagine-other condition. In this study, the different perspective-taking conditions did not lead to differences in muscle activity. This result was not moderated by amount of autism traits. M. orbicularis oculi

[16] Studies of (non-facial) motor imitation of non-pain conditions indicate that participants show reduced motor mimicry during high self-focus. However, as these conditions do not involve pain, the physiological response may be very different: In non-pain imitation tasks, a self-focused perspective may distract from the task at hand, whereas focusing on the self while imagining pain is likely to heighten awareness of the pain.

activity was increased from baseline in both the imagine-other and imagine-self conditions, and conversely, M. corrugator supercilii activity was not significantly greater than M. medial frontalis activity in either perspective. These results differ from Lamm and colleagues' (2008) findings on perspective-specific M. orbicularis oculi activation, but are consistent with participant's subjective affective state reports to the different perspectives. It may be that participants did not successfully switch between perspectives, leading to similar physiological and subjective responses to the two conditions. Alternatively, it may be that the same physiological reactions are activated whether thinking about own-pain or self-pain. These unconscious reactions may take place at an earlier stage than cognitive processes such as perspective taking. Increasing evidence on the overlap in neural areas that are activated when experiencing own pain and when observing others' pain (Avenanti et al., 2005; Lamm et al., 2011) supports this proposition.

In summary, the pattern of heightened M. orbicularis activity compared to baseline and to the M. medial frontalis response suggests that the empathy induction was successful. Once alexithymia was controlled for, neither amount of autism traits nor medication use predicted muscle amplitude. Deliberately taking the perspective of the target did not result in differences in muscle activation. The interaction effect between trait cognitive and affective empathy on change in muscle activity over time suggests that participants with high affective empathy and low cognitive empathy show heightened mimicry of facial expressions of pain, whereas participants with low affective empathy and high cognitive empathy show facial reactions consistent with surprise rather than concern. These results confirm the close connection between affective empathy and muscle mimicry.

Autonomic Arousal

Resting state autonomic arousal. In this study, I wished to replicate the results of Study 2 on a different day and time of measurement. Study 2 found no evidence for reduced parasympathetic arousal at baseline in participants with ASD. Resting state arousal was also not associated with state or trait measures of empathy. This study followed the same method for measuring resting state arousal as Study 2. Parasympathetic (cardiac vagal control) and sympathetic arousal (pre-ejection period and skin conductance level), as well as heart rate, was measured during a 2-minute period in which participants were asked to sit quietly with their eyes closed. Similar to the previous measurements, participants had heart rate, skin conductance, pre-ejection period and RSA scores within normal ranges (de Geus & van Doornen, 1996).

As was the case in Study 2, pre-ejection period, cardiac vagal control and skin conductance were not correlated with amount of autism traits. Heart rate was again significantly positively correlated with the amount of autism traits, though the correlation coefficient was small, and the effect disappeared when participants taking antidepressants[17] were removed from the analysis. Again, these results do not correspond with predictions of the polyvagal theory that resting state parasympathetic arousal is reduced in ASD (e.g., Porges, 2005; Porges et al., 2013; Vaughan Van Hecke et al., 2009). Neither was there any evidence of heightened sympathetic arousal at rest, as has been found in some studies (Anderson & Colombo, 2009). The latter study's results may be due to heightened anxiety in

[17] I specifically focused on antidepressants (rather than medication use in general, as was done for subjective and muscle response) because this group of medications have shown the greatest effect on heart rate and heart rate variability in previous studies (Licht, de Geus, van Dyck, & Penninx, 2010; Licht, Penninx, & de Geus, 2012).

a foreign environment in their (much younger) ASD sample, thus increasing 'resting state' sympathetic arousal.

Similar to Study 2, and contrary to hypotheses, cardiac vagal control was not associated with trait affective empathy, trait cognitive empathy or trait self-regulation. These results agree with previous findings that resting state cardiac vagal control is not correlated with dispositional empathy (Stellar et al., 2015). Unlike Study 2, baseline autonomic arousal was also not associated with subjective affective state (neither empathic concern nor personal distress) while observing pain. The difference in results between this study and Study 2 may be explained by the fact that resting state arousal predicted change in affect between non-pain and pain conditions in Study 2, not absolute levels of arousal. The current study did not contain non-pain stimuli with which to contrast the facial expressions of pain, and thus change scores could not be calculated. As arousal was correlated with change in affective state, but not absolute level of affective state, resting state arousal may be a better indicator of relative or minor regulation of affective states, rather than an indicator of general social-emotional disposition. Put differently, individuals with high resting state parasympathetic arousal reported both high and low levels of affective arousal to the videos (i.e., absolute level of affective state was not predicted), but they were better at maintaining their affective state levels between pain and non-pain conditions, and did not show big fluctuations between the conditions. Thus, there is tentative evidence of a link between resting state arousal and regulation of affective states (again, both empathic concern and personal distress).

As discussed in Chapter 2, few studies have measured the relationship between autonomic arousal and empathic concern specifically. One study that did examine this relationship found that girls (though not boys) with high heart rate variability had greater

dispositional empathic concern and lower self-reported distress (Fabes et al., 1993). However, the authors did not separate the predominantly parasympathetic heart rate variability frequencies (i.e., RSA) from frequencies related to sympathetic cardiac regulation and did not control for respiration. Thus, the association between empathic concern and heart rate variability in their study may have been caused by other uncontrolled physiological variables. A later study found no correlation between resting state RSA and empathic concern (Gill & Calkins, 2003), similar to what was found in the current study. Alternatively, the non-significant results found in this study may be because the current study consisted mainly of male participants, in whom Fabes and colleagues (1993) did not find a significant association between RSA and empathic concern. The use of informant reports of empathic concern in future work, for example from partners or parents, may provide more insight into the relationship between resting state autonomic arousal and empathic concern.

Autonomic response. A key hypothesis running through this thesis is that, once alexithymia is controlled, affective empathy is preserved in individuals with high amounts of autism traits. Study 2 measured sympathetic responses to physical pain as one indicator of affective empathy, and this study extends those findings (1) by measuring responses to facial expressions of pain rather than physical pain, and (2) by using longer stimuli so that parasympathetic reactivity could be measured. To my knowledge this is the first study to measure parasympathetic reactivity to empathy-for-pain stimuli in participants with ASD.

The facial expressions of pain elicited synergistic activation of the parasympathetic and sympathetic systems. This response was greatest in response to the first block of videos, and showed a steady return to resting state values during the subsequent blocks; with skin conductance showing the most sustained response throughout the task. This pattern of

activity is consistent with previous reports of increased RSA (i.e., parasympathetic activation) and reduced heart rate when watching others in distress (Stellar et al., 2015; Van Hulle et al., 2013) or in pain (Lepron et al., 2015); as well as reports of increased skin conductance from rest (sympathetic activation) when observing facial expressions of pain (Lanzetta & Englis, 1989; Vaughan & Lanzetta, 1980). Autonomic co-activation has also been associated with feelings of non-crying sadness or concern (Hastings & Miller, 2014; Kreibig, 2010), and as I argued in Chapter 2, may best predict empathic concern as it orients the onlooker towards the target's distress but prevents an unchecked fight-or-flight response.

Unsurprisingly, physiological arousal at baseline significantly predicted arousal during pain observation. Once baseline arousal was controlled for, video cycle had a significant effect on all indices: On average, cardiac vagal control and skin conductance level decreased and heart rate and the pre-ejection period increased during the second cycle of videos, corresponding with concomitant reductions in cardiac parasympathetic control and beta-adrenergic sympathetic arousal. The reduction in sympathetic arousal from cycle 1 to cycle 2 is in keeping with the idea that defensive, sympathetic reactions to witnessing another's pain are swiftly down-regulated to focus the attention on the other person and reduce personal distress in the onlooker.

There was a significant interaction in the effects of amount of autism traits and cycle on cardiac vagal control, skin conductance and heart rate. In participants with low amounts of autism traits, skin conductance level on average remained elevated while pre-ejection period and heart rate increased from the first to the second cycle, indicating decreasing parasympathetic arousal and unchanged to decreased sympathetic arousal (lower sympathetic arousal corresponds to longer pre-ejection period, while decreased parasympathetic arousal

corresponds to increased heart rate). As would be expected, arousal was visible for longer in skin conductance levels than in cardiac responses. Thus, participants with low autism traits had synergistic parasympathetic and sympathetic arousal, followed by a reduction in arousal in both systems. This pattern of autonomic change is consistent with the predictions of the neurovisceral integration theory, which predicts that active emotion regulation is associated with greater vagal flexibility (i.e., greater changes in cardiac vagal control).

Participants with high amounts of autism traits had significantly higher heart rates and skin conductance levels, and had similar cardiac parasympathetic arousal to participants with low autism traits during the first cycle of stimuli. This effect remained when participants who were on antidepressants were excluded. It is evident that, rather than having a reduced response to facial expressions of pain, participants with high amounts of autism traits had a heightened sympathetic response, similar to what would be expected in heightened personal distress. These results correspond to previous studies that showed heightened skin conductance to others' pain or facial displays of distress in individuals with ASD (Blair, 1999; Gu et al., 2015).

During the next cycle of videos, participants with high amounts of autism traits showed a reduction in skin conductance while heart rate and cardiac vagal control remained the same, indicating decreasing sympathetic activity with less change in parasympathetic arousal than was seen in participants with low autism traits. In other words, participants with high amounts of autism traits had greater changes in sympathetic arousal and reduced cardiac vagal flexibility. Amount of autism traits was not significantly related to physiological changes on its own, and again this effect did not change when controlling for antidepressants or medication use in general. The evidence suggests intact affective empathy, but poorer

autonomic self-regulation in participants with ASD. These results correspond with previous work suggesting that individuals with ASD fail to attenuate empathic neural and autonomic responses (Gu et al., 2015). Given that participants with high amounts of autism traits reported lower rather than higher affective states (both empathic concern and personal distress) when alexithymia was not controlled, an alternative explanation for the reduced cardiac vagal control is that high autism trait participants displayed less active coping because they were not as distressed by the stimuli as low autism trait participants were. However, this explanation does not seem feasible in light of the fact that participants with high amounts of autism traits had increased skin conductance – indicative of a threat response. Rather, the difference between the subjective reports and the autonomic results is most likely due to either poor awareness of bodily states or poor reporting thereof.

Neither personal distress nor any of the dispositional empathy measures (affective, cognitive and self-regulation) were significantly correlated with physiological responses. Furthermore, despite evidence of greater distress-related autonomic arousal, participants with high amounts of autism traits did not report higher subjective distress: Affective arousal was not correlated with autism traits when controlling for alexithymia; and before controlling for alexithymia, high autism trait participants reported lower affective arousal (both empathic concern and personal distress) than low autism trait participants. The lack of significant correlations between physiology and subjective report are consistent with previous research (Sun et al., 2015), and may again be related to the relatively small within-subject changes in autonomic arousal or suboptimal retrospective reporting of affective states. More research is needed to separate distress from concern, and to connect physiological, subjective and behavioural response to each other.

Limitations and Future Directions

A limitation of the study design is that only faces showing painful expressions were used. This was an established task that has been used before in other adult population groups (Lamm et al., 2007, 2008). To test for differences in arousal, the time period during facial pain was compared to the time period before pain started. However, participants could have had an anticipatory response to the pain. Furthermore, not having non-pain facial expressions meant that changes in pain perception and affective state could not be calculated, as was done in Study 2. Future studies should use stimuli of neutral and happy faces in addition to painful facial expressions to be able to explore the relationship between autonomic self-regulation and changes in affective state to different facial expressions.

To standardise stimuli, experimenters have generally only used videos of the area where the pain is applied or the facial expressions of pain. However, studies such as Sun et al. (2015) suggest that, for stimuli to have the strongest impact, both the application of pain and the facial expression of pain should be visible. Having only the facial expression visible may have reduced the size of the empathic response in this study. However, it allowed me to test an important aspect of empathy for pain in autism: Given that individuals with autism have difficulties interpreting basic facial emotional expressions, would they respond differently to faces in pain than to the application of pain? Future studies can vary the type of pain that is visible to explore the relationship between alexithymia, autism and empathic concern.

Lastly, the communicative aspect of facial muscle reactivity to pain should be explored further. Many researchers have argued that muscle mimicry indicates to others that you are aware of their situation, and conveys your concern to that party (Bavelas et al., 1986;

Hess & Fischer, 2013). Bavelas and colleagues (1986) have previously shown that muscle activity is heightened when the injured party faces the observer (versus turning away from the observer). This work can be extended by testing muscle reactivity to a person or avatar displaying facial pain, and manipulating the eye gaze of the avatar, for example. Muscle mimicry should be greater when the avatar makes direct eye contact, where there is greater opportunity to convey concern to the other person.

Summary and Conclusion

The aim of this study was to investigate whether autism traits are correlated with empathy for others' facial expressions of pain. This study also expanded on the results of Study 2 by simultaneously measuring parasympathetic and sympathetic reactivity in an empathy-for-pain paradigm; the first to my knowledge to do so. This study followed the same multilevel approach as in Study 2; measuring response to empathy induction via muscle reactivity, sympathetic and parasympathetic autonomic reactivity, along with subjective report.

There were several important findings in the study: Subjectively, participants reported feeling more empathic concern than personal distress. At the muscular level, the stimuli elicited significant increases in M. orbicularis activity, associated with narrowing the eyes. At the autonomic level, participants showed short-term co-activation of the sympathetic and parasympathetic autonomic nervous systems, followed by a concomitant reduction in cardiac parasympathetic control and beta-adrenergic sympathetic arousal. At the same time, participants reported heightened awareness of the target's pain, but not heightened affective states during the second cycle of videos. In other words, both pain intensity and pain unpleasantness ratings were higher in the second cycle (which consisted of two blocks, each

representing a different perspective), but neither empathic concern nor personal distress changed between cycles. These findings are consistent with the theory that effective autonomic arousal primes the individual for empathic concern, and inhibits personal distress.

Amount of autism traits was negatively correlated with perceived pain, but was not correlated with affective state once alexithymia was controlled for. Relatedly, amount of autism traits was not correlated with change in muscle activity over time, or raw muscle activity once alexithymia was controlled for. Also at the autonomic level, participants with high amounts of autism traits had similar increases in cardiac vagal control and showed heightened skin conductance and heart rate responses in comparison with those with low autism traits. These results show that to react with concern to facial expressions seems to require greater own-emotion understanding than does observation of physical pain, as alexithymia did not influence empathic concern for sensory pain in Study 2.

In contrast to alexithymia, poorer subjective self-regulation was associated with higher subjective affective states in response to the perceived pain, but was not correlated with the perceived unpleasantness or intensity of the pain. Though subjective trait self-regulation was not directly related to autonomic reactivity, there was some indication of poor autonomic self-regulation in ASD: Participants with higher autism traits had greater skin conductance and higher heart rates at cycle 1, and did not show changes in cardiac vagal regulation between cycles 1 and 2. This result is interpreted in terms of the neurovisceral integration model as poorer autonomic regulation of affect in the high autism trait individuals. To be able to draw firm conclusions, these results need to be replicated in future research. However, they resonate with the results of Studies 1 and 2 that show that affective empathy is intact in ASD, but autonomic self-regulation may be impaired.

In terms of the predictions of the neurovisceral integration model and polyvagal theory regarding the influence of resting state parasympathetic arousal on empathy and emotion regulation, baseline sympathetic and parasympathetic arousal were once again not associated with subjective ratings of trait or state affective empathy, trait cognitive empathy or trait self-regulation. Similar to study 2, these results do not support conclusions that resting state autonomic - and particularly parasympathetic – regulation is associated with dispositional socio-emotional factors. Muscle and autonomic reactivity were also not associated with state empathic concern or distress scores. In general, a goal for future empathy studies is to achieve greater coherence among different levels of measurement.

To conclude this chapter where it started, though the results do not speak to recognition of emotion, perhaps you do have to understand your own emotions – to "look into yourself" (Wittgenstein, 1967, p. 40e), to feel *concern* for the emotion portrayed on another's face.

CHAPTER 8.

GENERAL DISCUSSION

The Research Domain Criteria (RDoC) project has set researchers the aim of identifying the transdiagnostic biobehavioural mechanisms, at multiple converging levels of analysis, that trigger mental disorders (Cuthbert, 2014; Kozak & Cuthbert, 2016). In agreement with this aim, the motivation for this thesis was to describe the autonomic, muscular, cognitive, and subjective reactions associated with empathy in a group of individuals with varying levels of autism traits. The major theoretical proposition of this thesis is that empathy is not globally impaired in individuals with ASD, and that evidence of this supposition can be found at the various levels of analysis described above.

To test my proposition, I investigated affective empathy, cognitive empathy and self-regulation at the dispositional level using self-report. Cognitive empathy was also measured by two performance tasks, namely emotion recognition and recognition of social faux pas. Furthermore, I measured affective empathy, autonomic self-regulation, subjective empathic concern and communication of empathy (via facial and bodily muscle mimicry) in response to observed physical pain and facial expressions of pain. Autonomic regulation served as a marker for both affective empathy and the ability to regulate affective arousal (i.e., self-regulation). In this chapter I will integrate the empirical evidence from Studies 1 to 3 with the principal arguments of the previous chapters. I will describe the evidence for intact, impaired or heightened empathy facets in ASD, and discuss autonomic self-regulation as a potential

mechanism to explain the divide between (intact) affective arousal and (reduced) social engagement in ASD.

The Characteristics of Empathy in ASD

Amount of autism traits was not correlated with affective empathy to sensory pain at the trait or state level in self-report measures, nor with measures of autonomic reactivity. Similarly, muscle reactivity to sensory pain was not associated with amount of autism traits. In contrast, the relationship between autism traits and empathy for facial expressions of pain was mediated by alexithymia: Autism traits were negatively correlated with perceived pain, affective state and muscle amplitude; however, once alexithymia was controlled for, autism traits no longer predicted affective state or muscle amplitude in response to facial expressions of pain. At the autonomic level, participants with higher amounts of autism traits had intact parasympathetic and heightened sympathetic arousal to facial expressions of pain. These results suggest that non-alexithymic adolescents and adults with high levels of autism do not have reduced affective empathy for pain, regardless of whether they are observing sensory pain or facial expressions of pain. However, alexithymia is negatively correlated with affective arousal, empathic concern and muscle mimicry when observing facial expressions of pain (but not sensory pain). Subgroups of individuals with ASD may therefore present with reduced affective empathy and empathic concern, but this does not necessarily define individuals with high amounts of autism traits as a whole. Similarly, lack of awareness of bodily traits has been found to be associated with alexithymia, rather than ASD per se (Garfinkel et al., 2016; Shah, Hall, Catmur, & Bird, 2016). A caveat to this interpretation is that individuals with different levels of autism traits were not matched on alexithymia, so that

more participants with ASD had alexithymia than those with low autism traits. More studies such as that of Bird and colleagues (2010), where participants were matched on alexithymia, are needed to properly disentangle the effects of alexithymia and ASD. However, alexithymia was a better predictor of affective empathy than ASD in the statistical models. Moreover, alexithymia presents a possible *reason for* lower affective empathy to facial expressions in some individuals with ASD, and thus opens up new lines of enquiry. Furthermore, affective empathy and empathic concern were only reduced in alexithymic participants for complex pain stimuli, and were not affected when observing physical pain. In short, global deficits in empathy in ASD were not found.

Supporting evidence that affective empathy is intact in individuals with ASD comes from the psychopathy and morality literature. The profile of diminished affective empathy but intact cognitive empathy in psychopathy has been well established (e.g., Pfabigan et al., 2015; Schwenck et al., 2012). This profile makes psychopathy an ideal comparison group for ASD, in which cognitive empathy is impaired, but affective empathy skills are disputed. Individuals with psychopathic and disruptive behaviour show diminished autonomic and neural reactivity to viewing others' distress and pain (Decety, Chen, Harenski, & Kiehl, 2013; Jones et al., 2010), and report lower levels of dispositional affective empathy (Schwenck et al., 2012). They also evidence callous behaviour, disregard of others' welfare and emotion, and lack of remorse (Blair, 2008). In contrast, these behaviours are not normally associated with ASD. Individuals with ASD also show moral reasoning and behaviour, and reduced utilitarian behaviour (Patil, Melsbach, Hennig-Fast, & Silani, 2016); constructs that are positively correlated with affective empathy and reduced in psychopathy (Aaltola, 2014; Krahn & Fenton, 2009).

Why did initial studies of ASD report global deficits in empathy? As I argued in Chapter 2, part of the explanation is that different definitions are used. Some authors equate not understanding others' emotions, or even having limited social behaviour, with having a general deficit in empathy. For example, C. Gillberg (1996, p. 52) writes that "The failing skills in reciprocal social interaction and the theory of mind deficiencies could be seen to reflect or *be synonymous with* empathy deficits" [own emphasis]. Working on the definition of empathy as social behaviour, investigators have evaluated eye contact and consoling behaviour to measure empathy (e.g., Hobson et al., 2009). However, these constructs are not the same as empathy, and require additional skills.

The importance of not relying on outward behaviours to infer inner states cannot be stressed enough. For example, individuals with ASD often have reduced verbal and nonverbal communication of pain; and this has long been taken as a sign of reduced *sensitivity* to pain (Kolvin, Ounsted, Humphrey, & McNay, 1971; Militerni et al., 2000). However, more recent studies of physiological reactivity have shown intact or even heightened perception of own pain in ASD (Rattaz et al., 2013; Tordjman et al., 2009). To bring this back to empathy, participants high in affective empathy may not show prosocial behaviour because they have disrupted emotional regulation or do not have the cognitive skills or social experience to provide appropriate consoling behaviour. Alternatively, participants may have high affective empathy but avoid direct eye contact because of the intensity of affect sharing, as is often anecdotally reported by individuals with ASD (and has recently been shown in physiological studies, Kylliäinen et al., 2012; Kylliäinen & Hietanen, 2006). To illustrate this point, a recent population-based twin study (Van Hulle et al., 2013) found that children who showed passive disregard for others' distress (i.e., who showed no

eye contact, consoling behaviour, or communicative attempts) experienced *greater* arousal during the distress episode than children who showed either concern or active disregard (i.e., antisocial behaviours). Lack of behaviour expression does not indicate lack of affect.

With the increasing availability of psychophysiological equipment, affective arousal can be measured without having to rely solely on external behaviours that depend on many other factors besides empathy. Even so, the high rate of alexithymia in ASD has not always been accounted for, though it clearly influences subjective responses (Bird et al., 2010; Moriguchi et al., 2007). Visual attention has also not always been adequately controlled for, though it has been shown to influence empathy-related behaviours such as contagious yawning in ASD (Senju et al., 2009). Thus, another reason for the apparent global empathy deficits in ASD may be inadequate control of confounding variables.

Others, such as Baron-Cohen (Baron-Cohen & Wheelright, 2004; Golan & Baron-Cohen, 2006) and Frith (2003), have defined empathy in such a way that cognitive empathy is necessary for all other forms of empathy. These definitions presuppose a cognitive understanding of others' minds before any affective arousal sharing can take place. The emphasis on cognitive empathy is necessarily reflected in empathy questionnaires developed from this theoretical stance: Although Baron-Cohen and Wheelright (2004) describe empathy as having a cognitive and an affective component, their Empathy Quotient asks primarily about understanding others' emotions and thoughts. Only eight of the 60 questions in the full questionnaire, and two questions in the 22-item short form (Wakabayashi, Baron-Cohen, Wheelwright, Goldenfeld, et al., 2006), do not need intact cognitive empathy. Furthermore, of the two questions on the short form ("I really enjoy caring for other people", and "I tend to get emotionally involved in a friend's problems"), the first question addresses prosocial

motivation more than it does empathy. Most research reporting reduced empathy in ASD has used the Empathy Quotient, and equated poor scores to a *global* deficit in empathy, when in fact, the Empathy Quotient measures cognitive empathy almost exclusively (see Appendix Q). However, as I have argued in Chapter 2, developmental and neural studies of empathy do not support the idea that cognitive empathy is a necessary first step to affective empathy. These studies report affective arousal sharing in the first year of life, before basic mental state attribution skills have developed (Geangu, Hauf, et al., 2011; Roth-Hanania et al., 2011). The point to be made is that previous authors have concluded that individuals with ASD lack affective empathy because they measured related but functionally separate behaviours, only measured one part of empathy, or did not adequately control for confounding factors.

In contrast to the global empathy deficit hypothesis, the empathy imbalance hypothesis (A. Smith, 2009) speculates that individuals with ASD have *increased* affective arousal. I found tentative evidence of increased affective arousal in this thesis: Participants with high amounts of autism traits had higher heart rates and higher skin conductance when observing facial expressions of pain, though this was not true in the sensory pain condition. At the subjective level, neither affective states nor perceptions of pain were positively correlated with autism traits. However, I did find indications that individuals with high amounts of autism traits might be at greater risk of experiencing affective hyperarousal when observing the infliction of pain. Participants using medication, who mostly had high amounts of autism traits, reported greater subjective affective reactions (Study 2) and higher ratings of pain unpleasantness and intensity (Study 2)[18]. Participants with poor trait self-regulation also had increased affective responses (Studies 2 and 3) and heightened pain perception (Study 2).

[18] Participants using medication also had higher ratings of pain unpleasantness and intensity in Study 3, but this effect was no longer significant once alexithymia was controlled for.

Similar to medication use, poor trait self-regulation was associated with more autism traits in Study 1. However, at least in Study 2, these responses were associated with heightened subjective reports of affective states in all the conditions, not only to pain. This result implies that certain individuals with high amounts of autism traits may be prone to subjectively experiencing heightened affective states in general, not heightened empathy-specific arousal as proposed in the empathy imbalance hypothesis.

If reduced affective empathy is not at the heart of diminished or abnormal social behaviour, what is? Study 1 found negative correlations between cognitive empathy and autism traits at both the self-report and performance levels. Deficits in cognitive empathy in ASD are well-documented, and account for some of the social behaviour deficits in ASD. For example, better cognitive skills are associated with improved adherence to social rules (Baurain & Nader-Grosbois, 2013) in typically developing and intellectually disabled children and better social interaction skills in ASD (Bosacki & Astington, 2001). However, cognitive empathy is not correlated with many other aspects of social competence: Children with ASD who perform well on cognitive empathy (or theory of mind) tasks have better social insight than their ASD peers, but are no more sociable (Frith, Happé, & Siddons, 1994). Furthermore, cognitive empathy is not correlated with severity of social impairment in ASD (Joseph & Tager-Flusberg, 2004). Tellingly, interventions that teach cognitive empathy have not been very successful at improving social competence in ASD (Fletcher-Watson, McConnell, Manola, & McConachie, 2014; Solomon, Goodlin-Jones, & Anders, 2004). Poor cognitive empathy is thus unlikely to be the only cause of social-communicative difficulties in ASD.

If affective responses are not reduced in all individuals with ASD, and cognitive empathy does not predict the extent of social deficits, what else could explain the presentation of ASD? Alexithymia may explain some, but not all, social-communication deficits as it is not universally present in ASD (Berthoz et al., 2013). In addition to alexithymia, deficits in self-regulation may explain the impairments in social engagement seen in ASD.

Self-Regulation and Autonomic Arousal

Another possible contributor to the discrepancy between intact affective arousal and diminished social behaviour in individuals with high amounts of autism traits may be the ability to self-regulate. I found that amount of autism traits was negatively correlated with dispositional self-regulation ability in Study 1. These results agree with several other studies that suggest that emotion regulation is impaired in ASD (Dijkhuis, Ziermans, Rijn, Staal, & Swaab, 2016; Mazefsky et al., 2013; Samson et al., 2012). In this thesis, I specifically wanted to test whether (1) there is autonomic evidence of dysregulated affect while observing another's pain, and (2) whether resting state arousal could predict efficient autonomic regulation, and thus affective outcomes, during pain observation.

(1) Study 3 presented exploratory evidence of atypical autonomic regulation during affective empathy in participants with high amounts of autism traits: Participants with more autism traits tended to have higher sympathetic arousal during the first cycle of pain observation, and reduced changes in parasympathetic vagal regulation between cycles, indicative of poor regulation. Reduced vagal flexibility has been associated with challenging behaviour, reduced social behaviour, and increased negative emotionality (Calkins, Graziano,

& Keane, 2007; Calkins & Keane, 2004). Thus, there is tentative evidence for atypical autonomic regulation in response to empathy-inducing tasks in individuals with high amounts of autism traits, and evidence from other studies that such autonomic regulation differences can lead to difficulties in social behaviour.

(2) Regarding the use of resting state autonomic arousal as a predictor of self-regulation and social engagement, Study 2 demonstrated that participants with predominantly parasympathetic arousal (i.e., high parasympathetic arousal and low sympathetic arousal) at rest reported smaller changes in personal distress relative to those with autonomic co-inhibition (i.e., low parasympathetic and sympathetic arousal). In contrast, changes in empathic concern did not differ between the predominantly parasympathetic and co-inhibition groups. However, resting state sympathetic and parasympathetic arousal did not predict absolute affective state levels, as would be predicted from the neurovisceral integration (Thayer & Lane, 2000, 2009) and polyvagal (Porges, 2001, 2005) theories. Resting state autonomic arousal was also not correlated with dispositional self-regulation once alexithymia was controlled for. Thus, the proposed link between resting state autonomic arousal – in particular parasympathetic arousal - and social engagement was not sufficiently demonstrated in the current studies. Resting state autonomic arousal may be correlated with self-regulation ability; however, the evidence from this set of studies is limited.

In neither study was resting state respiratory sinus arrhythmia, cardiac vagal control (RSA controlled for respiration and tidal volume) or pre-ejection period associated with amount of autism traits. Initial findings of increased heart rate in individuals with high amounts of autism traits were likely due to antidepressant use, rather than atypical

neurological regulation. However, the effects of different types of medication on resting state heart rate and emotion regulation merit further investigation. In particular, more research is necessary to explore whether increased affective arousal to stimuli observed in Study 2 is due to the direct effects of medication on resting state autonomic arousal, the effect of comorbid psychiatric or subclinical disorders such as poor self-regulation that necessitate the use of medication, or due to other associated factors. Until such a time, it is important for clinicians to be aware of potentially heightened arousal in individuals with ASD who are on medication or show signs of poor self-regulation, and to consider including regulation techniques in interventions.

In short, autonomic regulation in ASD during affective tasks requires more attention. Most studies have focused on resting state arousal; yet atypical autonomic arousal does not seem to be a general characteristic of the broader autism phenotype. Cognitive empathy, affective empathy (wrongly, I've argued) and more recently alexithymia, have received attention as potential causes of the social behavioural impairments in ASD. Autonomic flexibility (though not necessarily arousal at rest) is another potential mechanism, and one that has not received much attention. Reduced autonomic flexibility may explain why, despite the ability to feel affective empathy for others, social reciprocity in impaired in ASD.

Limitations

A strength of this thesis is that multiple modalities were used to measure empathy. As each modality has its own methodological limitations, it is unlikely that error variance associated with a specific method is reflected in other modalities. Such a multimodal or multilevel study of empathy greatly increases the validity of measurement of the construct.

Empathy was also broken down into smaller components to separate constructs that likely arise from different neural areas, have different functions, and are differentially affected (Harari, Shamay-Tsoory, Ravid, & Levkovitz, 2010; Shamay-Tsoory et al., 2007; Völlm et al., 2006). A disadvantage of the multimodal approach is that it introduces complexity when measures do not show coherence across levels. The lack of correlation between autonomic, muscular and subjective forms of empathy is neither wholly unexpected nor indicative of failure to measure the construct. It is widely acknowledged that the correlation between multiple measures of emotion is weak (Cacioppo, Berntson, Sheridan, & McClintock, 2000; Mauss, Levenson, McCarter, Wilhelm, & Gross, 2005; Mauss & Robinson, 2009). Lack of convergence may partly be due to psychometric properties of the measures and the complexity of physiological processes. However, it is increasingly acknowledged that affective processes are multiply determined, and that different levels of analysis provide different information. For example, one study examining convergence of emotion measures found that, whereas self-report of personality traits and state affect was not correlated with physiological measures (in their case, EEG and startle responses), informant report was (Lieberman et al., 2016). On the other hand, self-reported experience is more closely linked to behaviour than physiological processes are (Mauss et al., 2005). Similarly, skin conductance is sensitive to arousal, whereas facial EMG appears to be more sensitive to emotion valence (Mauss & Robinson, 2009). The bottom line is that the more converging lines of evidence future studies have available, the better emotions and social functioning can be predicted. Asking participants to rate their emotions on a moment-to-moment basis during emotion-elicitation may provide a more accurate measure of affective states than dispositional or retrospective reports, and seems to be more strongly related to physiological

measures (Stellar et al., 2015). Future multilevel studies can use such 'online' ratings of affective states and empathic concern, as well as other sources of information such as informant report to increase measure convergence. Additionally, direct measures of attention, such as eye gaze monitoring, and central nervous system functioning, such as electroencephalogram (EEG) or functioning magnetic resonance imaging (fMRI) during the experience of empathy will make it easier to connect specific peripheral physiological changes to brain activation and mental state changes.

It has been shown that antipsychotics and antidepressants have anticholinergic properties which could have reduced the measured skin conductance levels (Society for Psychophysiological Research Ad Hoc Committee on Electrodermal Measures, 2012) and affected cardiac autonomic arousal at rest and in response to stressors. Antidepressants in particular have been shown to increase resting heart rate due to dampening of cardiac vagal control (Kemp et al., 2014; Licht et al., 2010). Different antidepressants also have different effects on sympathetic arousal (Licht et al., 2012). The use of medication was statistically controlled for in all the analyses, and the use of antidepressants was specifically controlled for in the cardiac autonomic analyses, where it was most likely to have an effect. However, this study did not have a big enough sample size to control for all the different effects of different types of medication. As most individuals with ASD are on some type of chronic medication, it would not have been possible to recruit a large enough sample of individuals who are medication-free. As many as 54 - 70% of individuals with ASD are on at least one psychotropic medication (Buck et al., 2014; Esbensen, Greenberg, Seltzer, & Aman, 2009) and if non-psychotropic medications are included, this number increases to 81%, or four out of five individuals (Esbensen et al., 2009)Another important reason why I did not only

sample participants who are medication-free is that such a group would not present a true picture of ASD; and would represent only a minority of cases – likely those who are least affected. More collaborative, multi-site investigations of ASD are needed so that investigators can obtain large enough sample sizes to control for the effect of medication use. Relatedly, future studies should control for the effects of comorbid psychiatric disorders, such as depression and psychosis, that may influence cardiac autonomic arousal separately from medication use (Alvares et al., 2016).

The affective state questions did not adequately distinguish between other-oriented feelings of empathic concern and self-oriented feelings of personal distress. At face value, the questions seem to address different concepts; for example, "how sympathetic did you feel?" (empathic concern) versus "how perturbed did you feel?" (personal distress). The questions have also been used in a number of previous studies, who report and interpret the two states as independent of each other. However, statistical analyses in this and other studies (Batson et al., 1991, 1997) show that the questions are not measuring entirely separate concepts. Better measurement of these two constructs is needed. Measuring empathic concern and personal distress accurately is important for theories of empathy, as empathic concern and personal distress are hypothesised to be separable and to lead to different types of behaviour. If these two constructs cannot be separately elicited or assessed in empathy-for-pain paradigms, the theories around the separation of self- versus other-focused distress need to be revised. Future research needs to create and test different self-report questions, and use behaviour measures in conjunction with self-report in order to distinguish appropriately between concern and distress.

Because of constraints on the amount of time that participants could come for assessments, intellectual functioning was not assessed. All participants were able to answer the questions, and most participants were recruited from schools and universities. Fitness level, height, weight, body mass index, smoking and sleeping habits, and other physiological characteristics of the participants that could have influenced the autonomic measures were also not recorded. Participants were asked not to exercise, smoke, eat, and drink caffeinated substances before coming to their sessions, but it is possible that there could have been a systematic bias in, for example, weight or fitness according to autism traits. Such a systematic bias could potentially affect cardiac measures (e.g., Grant, Viljoen, Janse van Rensburg, & Wood, 2012). Future studies should attempt to either statistically control for these factors, or recruit participants with similar physiological characteristics. Additionally, though participants ranged in their amount of autism traits, the sample was limited to participants who were able to respond to questions and attend to the stimuli. Thus, the results of this study may not be generalizable to individuals with severe forms of ASD.

RSA and pre-ejection period were measured during fairly short time-periods (< 5 minutes). It is possible that the nonsignificant correlations between physiological indices and autism traits or empathy were due to equipment and methods that are not sensitive enough to changes over a short time-period. However, there is evidence for high reliability of ultra-short-term heart rate variability; with both inter-day and intra-day measures having high test-retest consistency (Esco & Flatt, 2014; Nakamura et al., 2016). Furthermore, time periods were of the same length for different stimuli so that recording time would not influence calculations. Thus, the chosen time periods should not have adversely affected measurement reliability.

There is much debate in the literature about what comes first: The physiological mirroring of an affective state, followed by the triggering of that affective state (Gallese, 2007), or the automatic activation of neural states similar to the target's perceived emotional state, leading to physiological sequelae such as motor and autonomic reactions (Preston, 2007). The studies in this thesis were not designed to tease apart what comes first, emotion or physiology, and in fact, we will need much more time-sensitive measures and carefully controlled studies if we are ever to do that. There is likely also a two-way interaction between emotion and physiology, where either may augment or suppress the other. The aim of this thesis is to show how and whether these processes are affected in ASD, not the causal sequence of reactions when observing empathy-inducing stimuli. Future studies, such as studies of individuals with paralysed muscles (Oberman, Winkielman, & Ramachandran, 2007; Rives Bogart & Matsumoto, 2010) or the congenital inability to feel pain (Danziger, Prkachin, & Willer, 2006) are needed to tease apart the two processes.

Despite the limitations described above, the current studies provide important information on different facets of empathy in people with high amounts of autism traits. The studies also provide information towards characterising autonomic states and reactivity in individuals with different levels of autism.

Future Directions

The current studies focused on empathy for observed pain and facial expressions of pain. These results can be taken further by studying empathy for social pain, as was recently done by Krach and colleagues (2015) in an experiment on embarrassment. Previous research has also shown the importance of social context on empathy for pain. Future studies can

investigate whether individuals with ASD are as sensitive to social influences on empathy as neurotypical individuals are. For example, several studies have shown that people do not react in the same way to displays of pain from competitors or those they dislike as they do to likeable characters and those with whom they have an affiliation (Bourgeois & Hess, 2008; Lanzetta & Englis, 1989; Likowski, Mühlberger, Seibt, Pauli, & Weyers, 2008; Weyers, Mühlberger, Kund, Hess, & Pauli, 2009). It is conceivable that people with higher ASD traits may be less prone to show these social biases in empathy. Furthermore, watching videos of pain or distress is not the same as witnessing someone experience pain or distress off-screen. Our current knowledge of empathy can be expanded by testing empathy for pain in naturalistic social interactions. For example, an experimenter can feign getting hurt, and can code participants' displays of concern, as well record participants' ratings about how distressed or concerned they felt during the event.

This study did not measure cognitive or behavioural emotion regulation strategies. Future research should test the association between autonomic regulation and cognitive self-regulation, empathy and distress in ASD by using self-report emotion regulation questionnaires such as the Emotional Control Questionnaire (Roger & Najarian, 1989) or Emotion Regulation Questionnaire (Gross & John, 2003). Autonomic and cognitive regulation measurements could also be supplemented by behavioural observations of regulation, such as behaviour during frustrating non-reward conditions, disappointment paradigms, or reward delay assessments (Mazefsky et al., 2013). Furthermore, studies have indicated that *whether* individuals are likely to use self-regulation strategies is not the only predictor of empathic concern and willingness to help, but also *what type* of regulation

strategies are being used (Gross, 2001; Lebowitz & Dovidio, 2015). Thus, future studies should distinguish between the effects of different types of regulation strategies.

The areas of overlap and non-overlap between alexithymia and ASD, and their associations with empathy, need further investigation. Studies need to recruit different psychiatric and non-psychiatric populations with and without alexithymia to tease apart the effects of these conditions on empathy and prosocial behaviour. Moreover, a limitation in most alexithymia studies is that self-report is predominantly used to measure lack of insight into own emotions. Though previous research has shown that self and observer reports of alexithymia are significantly correlated (Berthoz, Perdereau, Godart, Corcos, & Haviland, 2007), it may be prudent for researchers to include multiple paradigms for measuring alexithymia. Observer measures of alexithymia such as the California Q-Set Alexithymia Prototype (Haviland & Reise, 1996) or Beth Israel Hospital Psychosomatic Questionnaire (Sifneos, 1973) can be included in future studies.

There is preliminary evidence that resting state cardiac vagal control only predicts empathy in individuals with low attachment anxiety (Diamond et al., 2012). Future studies should investigate whether attachment, anxiety and emotion regulation mediate the relationship between physiological arousal, particularly cardiac vagal control, and empathy.

Summary and Conclusions

This thesis is the first to investigate the autonomic contributions to the regulation of empathy within ASD. Sympathetic and parasympathetic reactivity to empathy was measured concurrently in order to study the interaction effect of the two autonomic branches on empathic concern. Furthermore, empathy and its related phenomena of empathic concern and

muscle mimicry were measured at different levels of analysis. Using this multilevel approach, evidence for global deficits in empathy in ASD was not found: A higher amount of autism traits was not associated with reduced autonomic, muscular or subjective affective responses to observed physical pain or facial expressions of pain once alexithymia was controlled for. These findings were the same across multiple modalities and across several studies conducted over different days. In fact, contrary to the global empathy deficit hypothesis, there was evidence that individuals with high amounts of autism traits may be more likely to possess traits that are associated with heightened affective reactions, particularly to physical pain: Autism traits were negatively correlated with trait self-regulation, and poor trait self-regulation was associated with heightened subjective affective states. Medication use was also associated with heightened affective reactivity, potentially related to the effects of psychotropic medications such as antidepressants on resting state arousal. Alexithymia, however, was associated with lower subjective and muscular responses to perceived facial expressions of pain. Thus, autism traits were not associated with atypical affective empathy *per se*, though individuals with poor self-regulation or those on medication may show heightened affective arousal to others' pain, whereas individuals with comorbid alexithymia may show reduced arousal to painful expressions.

There was limited evidence of the neurovisceral integration and polyvagal theories' assertions that resting state arousal affects the ability to self-regulate: Heightened parasympathetic arousal and low sympathetic arousal at rest predicted smaller changes in personal distress to the pain stimuli. Furthermore, though resting state arousal was not associated with amount of autism traits, there was evidence of reduced changes in parasympathetically-mediated cardiac vagal control and heightened sympathetic arousal

during observation of pain expressions in participants with high amounts of autism traits. These results suggest dysregulated emotion regulation; however, this conclusion must remain speculative for now as the autonomic data were not correlated to subjective reports of affect. Expanding research paradigms to also include informant report, a behavioural component, brain imaging, or other forms of affect measurement, may help to clarify the link between autonomic arousal, empathy and prosocial behaviour.

Finally, I did not find correlations between resting state parasympathetic or sympathetic arousal and autism traits once antidepressants were controlled for. Moreover, resting state arousal was not associated with dispositional empathy or with absolute levels of affective states during pain observation. The non-significant findings regarding resting state autonomic arousal show that we need to understand the basic mechanisms in the link between autonomic regulation and social engagement much better before we can apply basic research in this area to physiological interventions, whether for ASD or for other disorders. In the last few years there has been an increasing interest in physiological interventions for ASD stemming from the optimism of the polyvagal theory's proposal that social engagement deficits in ASD may be reversible, and that the pathways between cardiac vagal control and social engagement are understood. For example, there are several lines of intervention research on stimulation of the vagus nerve (Oberman & Enticott, 2015; Y. Wang et al., 2015) and on physiology-based affect recognition by robots (Liu, Conn, Sarkar, & Stone, 2008). The negative results of this thesis caution against the premature use of potentially expensive and ineffectual physiological interventions before the nature of autonomic regulation in ASD is well understood and the relationship between autonomic arousal and social-communication is better characterised. For example, parasympathetic arousal at rest was not associated with

autism traits in the sample in general. Theories of parasympathetic dysregulation may only apply to a small subset of ASD. In this regard, more research on autonomic regulation is needed on well-defined, genetically similar subgroups in ASD, such as fragile X syndrome, in which the most promising evidence for resting state autonomic dysregulation has thus far been found. For now, hope of a biomarker or targeted physiological intervention in ASD remains elusive.

Of course, the results of this thesis are not only of relevance to the autism population, but increase our understanding of the physiological correlates of empathy in general. For example, as the first study to measure both sympathetic and parasympathetic arousal during empathy for pain, this work shows a clear co-activation of the sympathetic and parasympathetic branches of the nervous system when feeling empathy; a very different response than what has been shown for sustained attention or threat-induction tasks, where parasympathetic inhibition is the norm. The results also highlight the importance of own emotion understanding in the formation of empathy to more complex distress cues. Alexithymia was negatively correlated with affective states and with muscle mimicry when perceiving others' facial expressions of pain. Interventions to improve social behaviour would do well to include own-emotion understanding skills as part of the programme. This approach could be beneficial both in ASD and in other psychiatric groups with high comorbidities with alexithymia. Similarly, improving self-regulation skills may benefit not only individuals with ASD, but also others with emotion regulation difficulties.

A strength of this study was its dimensional approach. It is important to study disorders using a continuous approach not only because it allows for more statistical power, but also because it sheds light on a vulnerable group that is not usually studied – those with

subclinical traits. Studies have shown that older individuals who fall on the broader autism phenotype are at greater risk for depression, lack of social support and anxiety (Wallace, Budgett, & Charlton, 2016). Yet little is known about this group of people. The results from this thesis suggest that they may be vulnerable to alexithymia, poor self-regulation and lower cognitive empathy. However, as these individuals are not diagnosed, they may also be less able to access clinical support. More research is needed on the empathy and social engagement profile of this group. By better describing the mechanisms of empathy and social engagement in *all* individuals, we generate insight into how to create targeted interventions for all those who need it.

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APPENDIX A

UNIVERSITY OF CAPE TOWN ETHICS APPROVAL

UNIVERSITY OF CAPE TOWN

Department of Psychology

University of Cape Town Rondebosch 7701 South Africa
Telephone (021) 650 3414
Fax No. (021) 650 4104

16 January 2013

Michelle Hoogenhout
Department of Psychology
University of Cape Town
Rondebosch 7701

Dear Ms Hoogenhout,

This is to confirm that ethical clearance for the study "Examining empathy in autism spectrum disorders: Cognitive and physiological responses", has been granted by an Ethics Review Committee of the Faculty of Humanities of the University of Cape Town on 6 June 2012. The reference number is PSY2012/003.

I trust that you will find this in order, but please do not hesitate to contact us if further information is required.

Yours sincerely,

Signed

Johann Louw
Professor and Chair: Ethics Review Committee

Faculty of Humanities
Postgraduate Administration
University of Cape Town

Room 1.05, Beattie Building
Private Bag X3, Rondebosch 7701
Tel: +27 (0) 21 650 4414 Fax: +27 021 650 5751
E-mail: anne.wegerhoff@uct.ac.za
Website: http://www.humanities.uct.ac.za/postgraduate/gradschool/aboutus/

21 June 2012

Dear Ms Hoogenhout

PhD PROPOSAL

I have pleasure in advising that your research proposal as detailed below has been accepted by the Department of Psychology, and the Faculty of Humanities, and was recommended to the Doctoral Degrees Board for approval in the Dean's Circular HUM 04/2012. You will receive formal notification of your candidature from the DDB in due course.

I have attached the Doctoral Degrees Board guidelines for supervisors and candidates for your information.

Best wishes

Signed

ANNE WEGERHOFF
GRADUATE PROGRAMMES OFFICER

cc Dr S Malcolm-Smith/Dr K Thomas

Name	Student #	1st Reg	Title	Supervisor	Co-supervisor
Hoogenhout M	RBBMIC002	03-Jun-11	Examining empathy in autism spectrum disorders: cognitive, behavioural and autonomic responses to facial emotion recognition, perception of pain and the detection of social transgressions	Dr S Malcom-Smith	Dr K Thomas

ETHICAL APPROVAL FOR STUDY AMENDMENT

The study titled, "Examining Empathy in Autism Spectrum Disorders: Cognitive, Behavioural and Autonomic Responses to Facial Emotional Recognition, Perception of Pain and the Detection of Social Transgressions" has been amended and requires ethical approval for this amendment, in addition to the already approved ethics to conduct psychological research with human subjects (reference number PSY2012/003).

Proposed Additions to the Study

The proposed change in procedure entails adding another assessment session to the currently approved two assessment sessions. The additional assessment session will be the first of the three assessment sessions to be completed, and will be used as a means to confirm a diagnosis of Autism Spectrum Disorder (ASD) using a trusted, reliable and standardized assessment tool called the Autism Diagnostic Observation Schedule-2 (ADOS-2). This tool has been designed to elicit ASD characteristics.

Participants will attend UCT's Child Guidance Clinic or the Division of Child and Adolescent Psychiatry for the additional assessment. Individuals highly trained in the ADOS-2 and deemed research reliable in the measure will then administer the ADOS-2. The ADOS-2 assessment consists of several play-based tasks and questions about the participant's school and work life, relationships and aspirations, all designed to elicit autism behaviours. This assessment takes approximately 1 hour. Participants will be seen in a private assessment room and the session will be recorded for later diagnostic viewing to confirm the ADOS-result. Three professional clinicians highly experienced in ASD diagnoses and blind to the results of the ADOS-2 assessment, will then watch the recorded ADOS-2 assessment and together reach a consensus diagnosis based on the reviewed material and their clinical judgement. The diagnostic assessments and the consensus diagnoses reached by the clinicians will confirm whether or not the participants have ASD. The recording of the session and review by expert clinicians is necessary as the ADOS-2 has not yet been validated as a diagnostic tool in South Africa.

Rationale for Amendments to Study

The need for the extra diagnostic session arises from two developments. Firstly, it is becoming more common in published research that using clinician diagnosis on its own is not enough to establish ASD diagnosis; rather most published studies now include an ADOS diagnostic assessment. Secondly, the data collected from this study will contribute towards a large scale study in Cape Town to validate the ADOS-2 in South Africa (PI: Dr Malcolm-Smith).

Ethical Considerations

The current consent form will be amended to include consent to be filmed during the diagnostic assessment. The recorded material, like the rest of the data, will only be available to the research team and the expert clinicians involved, and will be stored securely at UCT in a locked file cabinet or password-secured computer. Participants will be told about the study and the assessment sessions and encouraged to ask any questions they may have before giving informed consent. They will be notified that their information will be kept strictly confidential, and their data will be used in the study, but *they* will remain entirely anonymous in published material. Moreover, their information will be kept without their names or personal identifiers, and only codes will be used. Participants will also be told that they may discontinue their participation in the study at any time without any negative consequences. Once the participants are comfortable with the study and the procedure, the assessment session will commence.

There is minimal added risk to partaking in this additional assessment session. If participants request information about the diagnostic session, they will be given feedback about the outcome of the assessment after clinical consensus diagnosis has been reached. If participants require further support after the diagnostic session, they will be given contact details of local clinicians specialising in ASD.

Should you require any more information concerning the amendment or the study, please do not hesitate to contact the principal researchers Michelle Hoogenhout (082 597 8518) or Dr Malcolm-Smith (021 650 4605).

APPENDIX B

APPROVAL TO ADVERTISE RESEARCH ON CAMPUS

	RESEARCH ACCESS TO STUDENTS	DSA 100

NOTES

1. This form must be FULLY completed by applicants that want to access UCT students for the purpose of research.
2. Return the completed application form in same word format together with your research proposal and email to: Moonira.Khan@uct.ac.za
3. The turnaround time for a reply is approximately 10 working days.
4. NB: It is the responsibility of the researcher/s to apply for and to obtain ethical clearance and access to staff and/or students, respectively to the (a) Faculty's Ethics Research Committee' (FREC) for ethics approval, and (b) Executive Director, HR for approval to access staff for research purposes and the (c) Executive Director, Student Affairs for approval to access students for research
5. For noting, a requirement of UCT (according to Senate Research Protocols) is that items (1) and (4) apply even if prior clearance has been obtained by the researcher/s from any other institution.

SECTION A: RESEARCH APPLICANT/S DETAILS

Position	Staff / Student No	Title and Name	Contact Details (Email / Cell / land line)
A.1 Student Number	RBBMIC002	Ms. Michelle Hoogenhout	michellehoog@gmail.com/ 0825978518
A.2 Academic / PASS Staff No.			
A.3 Visiting Researcher ID No.			
A.4 University at which a student or employee	University of Cape Town	Address if *not* UCT:	
A.5 Faculty/ Department/School	Faculty of Humanities/ Department of Psychology		
A.6 APPLICANTS DETAILS If different from the researcher	Title and Name	Tel.	Email

SECTION B: RESEARCHER/S SUPERVISOR/S DETAILS

Position	Title and Name	Tel.	Email
B.1 Supervisor	Dr. Susan Malcolm-Smith	0216504605	susanmalcolmsmith@gmail.com
B.2 Co-Supervisor/s (a)	Dr. Kevin G. F. Thomas	0216504608	Kevin.Thomas@uct.ac.za

SECTION C: APPLICANT'S RESEARCH STUDY FIELD AND APPROVAL STATUS

C.1 Degree (if a student)	PhD
C.2 Research Project Title	Examining empathy in Autism Spectrum Disorders: Cognitive, behavioural and physiological responses
C.3 Research Proposal	Attached: Yes [x] No [ ]
C.4 Target population	Male students (with and without ASD), ages 18 - 30
C.5 Lead Researcher details	If different from applicant:
C6. Will use research assistant/s	Yes [x] No [ ]
C.7 Research Methodology and Informed consent:	Informed consent will be obtained: Yes Methodology: Quasi-experimental design. See proposal for further details.
C.8 Ethics clearance status from UCT's Ethics in Research Committee (EiRC)	Approved by the EiRC: Yes [x] No [ ] Awaiting response : [ ] If yes, attach copy and state the date and ref. no of FREC approval: Approval date 08/08/2012; ref. no. PSY2012/003 If awaiting response, indicate the date and Faculty of application : If no, indicate when and to which Faculty's REC you will apply:

SECTION D: APPLICANT/S APPROVAL STATUS FOR ACCESS TO STUDENTS FOR RESEARCH PURPOSE

(To be completed by the ED, DSA or Nominee)

APPROVAL STATUS	Approval status: Yes / No/ With Terms	Terms:		Applicant/s Ref. No.:
	Yes [x]	*Research may only be undertaken after ethics approval has been obtained from the relevant UCT FREC, in writing.*		RBBMIC002 / Ms Michelle Hoogenhout
APPROVED BY:	Designation	Name	Signature	Date
	Executive Director Department of Student Affairs	*Moonira Khan*	Signed	*17 February 2013*

APPENDIX C

WESTERN CAPE EDUCATION DEPARTMENT STUDY APPROVAL

Western Cape Government
Education

Directorate: Research

Audrey.wyngaard@westerncape.gov.za
tel: +27 021 467 9272
Fax: 0865902282
Private Bag x9114, Cape Town, 8000
wced.wcape.gov.za

REFERENCE: 20140725-33654
ENQUIRIES: Dr A T Wyngaard

Mrs Michelle Hoogenhout
3 Chalfont Road
Claremont

Dear Mrs Michelle Hoogenhout

RESEARCH PROPOSAL: EXAMINING EMPATHY IN AUTISM SPECTRUM DISORDERS: COGNITIVE, BEHAVIOURAL AND AUTONOMIC RESPONSES

Your application to conduct the above-mentioned research in schools in the Western Cape has been approved subject to the following conditions:

1. Principals, educators and learners are under no obligation to assist you in your investigation.
2. Principals, educators, learners and schools should not be identifiable in any way from the results of the investigation.
3. You make all the arrangements concerning your investigation.
4. Educators' programmes are not to be interrupted.
5. The Study is to be conducted from **28 July 2014 till 30 September 2014**
6. No research can be conducted during the fourth term as schools are preparing and finalizing syllabi for examinations (October to December).
7. Should you wish to extend the period of your survey, please contact Dr A.T Wyngaard at the contact numbers above quoting the reference number?
8. A photocopy of this letter is submitted to the principal where the intended research is to be conducted.
9. Your research will be limited to the list of schools as forwarded to the Western Cape Education Department.
10. A brief summary of the content, findings and recommendations is provided to the Director: Research Services.
11. The Department receives a copy of the completed report/dissertation/thesis addressed to:

    The Director: Research Services
    Western Cape Education Department
    Private Bag X9114
    CAPE TOWN
    8000

We wish you success in your research.

Kind regards.
Signed: Dr Audrey T Wyngaard
Directorate: Research
DATE: 25 July 2014

Western Cape Government
Education

Directorate: Research

Audrey.wyngaard@westerncape.gov.za
tel: +27 021 467 9272
Fax: 0865902282
Private Bag x9114, Cape Town, 8000
wced.wcape.gov.za

REFERENCE: 20140725-33654
ENQUIRIES: Dr A T Wyngaard

Mrs Michelle Hoogenhout
3 Chalfont Road
Claremont

Dear Mrs Michelle Hoogenhout

RESEARCH PROPOSAL: EXAMINING EMPATHY IN AUTISM SPECTRUM DISORDERS: COGNITIVE, BEHAVIOURAL AND AUTONOMIC RESPONSES

Your application to conduct the above-mentioned research in schools in the Western Cape has been approved subject to the following conditions:

1. Principals, educators and learners are under no obligation to assist you in your investigation.
2. Principals, educators, learners and schools should not be identifiable in any way from the results of the investigation.
3. You make all the arrangements concerning your investigation.
4. Educators' programmes are not to be interrupted.
5. The Study is to be conducted from **26 January 2015 till 25 June 2015**
6. No research can be conducted during the fourth term as schools are preparing and finalizing syllabi for examinations (October to December).
7. Should you wish to extend the period of your survey, please contact Dr A.T Wyngaard at the contact numbers above quoting the reference number?
8. A photocopy of this letter is submitted to the principal where the intended research is to be conducted.
9. Your research will be limited to the list of schools as forwarded to the Western Cape Education Department.
10. A brief summary of the content, findings and recommendations is provided to the Director: Research Services.
11. The Department receives a copy of the completed report/dissertation/thesis addressed to:

    The Director: Research Services
    Western Cape Education Department
    Private Bag X9114
    CAPE TOWN
    8000

We wish you success in your research.

Kind regards.
Signed: Dr Audrey T Wyngaard
Directorate: Research
DATE: 22 January 2015

APPENDIX D

CONSENT FORMS

Consent Form: Adult Participants

UNIVERSITY OF CAPE TOWN
DEPARTMENT OF PSYCHOLOGY

Examining the Physiological Response to Perceiving Another's Emotions

You are invited to take part in a research study.

Principal Researchers:

Dr. Susan Malcolm-Smith
Lecturer
Department of Psychology
University of Cape Town
021-650-4605

Michelle Hoogenhout
Doctoral candidate
Department of Psychology
University of Cape Town
082 597 8518

This study will look at how your body responds (through changes in heart rate, sweating and muscle movements, for example) to seeing another person's emotions or seeing another person in pain. We would like to see whether people with Autism Spectrum Disorder (ASD) respond the same as or different to neurotypical individuals. Approximately 100 people between the ages of 14 and 45 will participate.

Procedure

If you consent to participating in this study, you will be asked to come to the Department of Psychology for 3 sessions. The first session will be a diagnostic session of about 1-hour long. The first session will be recorded for diagnostic purposes. The tapes will only be watched by authorized researchers at UCT, and will be erased afterwards. These tapes will also not be published.

The next two sessions are each 2 hours long. During these two sessions you will be shown short video clips of people in physically painful or emotionally distressing situations. You will also be shown videos of people experiencing various emotions. During the videos, heart rate, sweating and muscle movements will be measured by placing electrodes on the skin. There are no risks involved in the

procedure. Participation is voluntary.

Risks, Discomforts & Inconveniences

Participants will be required to wear electrodes on their chest, face and hands to measure bodily responses. You may find this uncomfortable. However, the electrodes are not harmful in any way. You will also be asked to watch videos of people in physically painful or emotionally distressing situations. If you think that this footage might be upsetting to you, you are under no obligation to participate. Also, if you participate and find any of the procedures uncomfortable at any time during the experiment, you are free to discontinue participation without penalty.

Benefits

The information from this study may help improve our understanding of how people with ASD perceive and experience other people's emotions, specifically with regard to painful experiences.

Privacy and Confidentiality

We will take strict precautions throughout the study to keep your personal information safe and confidential. Your information will be kept without your name or other personal identifiers, only a code, in a locked file cabinet or on a password-protected, secure computer. Only certain people have the right to review these research records. These people include the researchers for this study and certain University of Cape Town officials. The data gathered from this research may be published, but your contribution will remain anonymous.

Money Matters

If you have been recruited through the Student Research Participation Programme (SRPP), you will receive 10 SRPP points upon completion of the study. If you have been recruited outside of the SRPP system, you will receive R100 for participation in the study.

Should you have any questions or queries about the research or your participation, please do not hesitate to contact Michelle Hoogenhout: (cell) 082 597 8518, (email) michellehoog@gmail.com

Consent Form

The study has been explained to me, and my questions have been answered.

I understand that participation in this study is voluntary, and that I may withdraw at any point.

I understand that I will not be identified except by an initial, and that this anonymity will be maintained throughout the study and when the research is published.

I consent to participate in this study and that the diagnostic session may be filmed.

Name _____
Signature _____
Date _____

I have explained the study to the participant, and in my opinion he understands that participation is voluntary and is able to give informed consent.

Researcher _____
Signature _____
Date _____

Use of Samples/Data for Future Research

With your permission, we would like to store the unused parts of your tests for use in future research. This is your choice entirely and you are free to say no; you will still be able to take part in the study. Please check the boxes that apply to your choice:

I do <u>not</u> want my samples to be used for any future research. ___

You may use my samples for any future research. ___

Please indicate below if you would like to be notified of future research projects conducted by our research group:

_____ (initial) Yes, I would like to be added to your research participation pool and be notified of research projects in which I might participate in the future.

Method of contact:

Phone number: _____
Cell phone number: _____
E-mail address: _____
Mailing address: _____
_____
_____

Consent Form: Adolescent Participants

UNIVERSITY OF CAPE TOWN

DEPARTMENT OF PSYCHOLOGY

Examining the Physiological Response to Perceiving Another's Emotions and Pain:
Information for parents

Dear Parents, we need your help!

This study looks at how people's bodies respond (through changes in heart rate and sweating, for example) to seeing another person's emotions or seeing another person in pain. We would like to see whether people with Autism Spectrum Disorder (ASD) respond the same as or different to typical individuals without ASD. The ultimate aim of the study is to provide better interventions for people who have autism. Participating learners will have the opportunity to advance scientific knowledge, gain insight into the university research process and, in the long run, improve interventions for developmental disabilities. Learners who have an interest in medicine, psychology or sport should find the study particularly interesting. They will have the opportunity to get real-time feedback about their heart rate and fitness. The study has approval from the Western Cape Education Department and the Department of Psychology Ethics Committee.

If your child would like to participate, please return the consent form to the school secretary by no later than Friday 1 May, sign up at http://uctautism.com or call Michelle Hoogenhout on 082 597 8518.

Approximately 100 people between the ages of 14 and 45 will participate. Just because you have received this letter, does not mean that your child has Autism Spectrum Disorder. We are now recruiting participants with no health or developmental problems.

Principal Researchers

Dr. Susan Malcolm-Smith
Lecturer
Department of Psychology
University of Cape Town
021-650-4605

Michelle Hoogenhout
Doctoral candidate
Department of Psychology
University of Cape Town
082 597 8518

Procedure

If you consent to your child participating in this study, your child will be asked to come to the Department of Psychology for 3 sessions. These sessions can be after school hours to not affect your child's school work. In the first session, your child will play some games and be asked some questions about themselves. The first session will be recorded for diagnostic purposes. The tapes will only be watched by authorized researchers at UCT, and will be erased afterwards. These tapes will also not be published. The first session is approximately one-hour long.

The next two sessions are each 2 hours long. During these two sessions your child will be shown short video clips of people in physically painful or emotionally distressing situations. However, none of the movies have more than a PG (parental guidance advised) rating. Your child will also be shown videos of people experiencing various emotions. During the videos, heart rate, sweating and muscle movements will be measured by placing electrodes on the skin. There are no risks involved in the procedure. Participation is voluntary.

Benefits

The information from this study may help improve our understanding of how people with ASD perceive and experience other people's emotions, specifically with regard to painful experiences.

Money Matters

Your child will receive R100 for participation in the study.

Risks, Discomforts & Inconveniences

Participants will be required to wear electrodes on their chest, face and hands to measure bodily responses. Your child may find this uncomfortable. However, the electrodes are not harmful in any way. Your child will also be asked to watch videos of people in physically painful or emotionally distressing situations. If you think that this footage might be upsetting to him or her, you are under no obligation to participate. Also, if your child decides to participate and finds any of the procedures uncomfortable at any time during the

experiment, they are free to discontinue participation without penalty.

Privacy and Confidentiality

We will take strict precautions throughout the study to keep your personal information safe and confidential. Your child's information will be kept without your name or other personal identifiers, only a code, in a locked file cabinet or on a password-protected, secure computer. Only certain people have the right to review these research records. These people include the researchers for this study and certain University of Cape Town officials. The data gathered from this research may be published, but your child's contribution will remain anonymous.

For more information visit http://uctautism.com. Should you have any questions or queries about the research or your participation, please do not hesitate to contact Michelle Hoogenhout: (cell) 082 597 8518, (email) michellehoog@gmail.com.

Consent Form

The study has been explained to me, and my questions have been answered.

I understand that my child's participation in this study is voluntary, and that he may withdraw at any point.

I understand that my child will not be identified except by an initial, and that this anonymity will be maintained throughout the study and when the research is published.

I consent to allow my child to participate in this study.

Name of child_____
Parent's signature _____
Date _____

Contact details

Phone number: _____
Cell phone number: _____
E-mail address: _____
Mailing address: _____
_____
_____

Future Research

With your permission, we would like to store the unused parts of your tests for use in future research. This is your choice entirely and you are free to say no; you will still be able to take part in the study. Please check the boxes that apply to your choice:

I do <u>not</u> want my child's samples to be used for any future research. ___

You may use my child's samples for any future research. ___

Please indicate below if you would like to be notified of future research projects conducted by our research group:

_____ (initial) Yes, I would like to be added to your research participation pool and be notified of research projects in which I might participate in the future.

APPENDIX E

ASSENT FORM

Hello! We want to tell you about a research study we are doing. A research study is a way to learn more about something.

Our study looks at how your body responds (through changes in heart rate, sweating and muscle movements, for example) to seeing another person's emotions or seeing another person in pain. People between the ages of 16 and 30 can take part.

Procedure

If you agree to join this study, you will be asked to come to the Department of Psychology at the University of Cape Town for 3 sessions. The first session will be approximately an hour long, and the next two sessions approximately 2 hours long. You will watch short video clips of people in physically painful or emotionally distressing situations. You will also see people experiencing various emotions. If you think that this might be upsetting to you, you do not have to participate.

During the videos, we will measure your heart rate and sweating by placing recording disks on the skin. Recording disks are like plasters with wires on them. The recording disks will be put on your chest, face and hands and can tell us what is happening inside your body. The recording disks are not harmful in any way. You may find the recording disks uncomfortable though. In that case, you do not need to participate in the study. It is your choice and no one will force you to take part. Also, if you participate and find any of the procedures uncomfortable at any time during the experiment, you are free to discontinue participation without penalty.

Benefits

The information from this study may help improve our understanding of how people perceive and experience other people's emotions, specifically with regard to painful experiences. You will also receive R100 for participation in the study.

Any questions?

If you sign your name below, it means that you agree to take part in this research study.

Date_____

Signature_____

APPENDIX F

DEBRIEFING FORM

Thank you for participating in the research study.

This form provides you with information about the study in which you have just participated, and explains in full the methods of collection of data for this research study. If there is anything else that you would like to know, the person in charge of this research will also explain this study to you in full and answer all of your questions.

1. Name of Participant

_____

2. Title of Research Study

Examining Empathy in Autism Spectrum Disorders: Cognitive, Behavioural and Autonomic Responses

3. Principal Investigators, Ethics Committee, and Telephone Numbers

Dr. Susan Malcolm-Smith	Michelle Hoogenhout
Lecturer	Doctoral candidate
Department of Psychology	Department of Psychology
University of Cape Town	University of Cape Town
021-650-4605	082 597 8518

Department of Psychology Research Ethics Committee

Tel: 021 650-3417

Email: rosalind.adams@uct.ac.za

4. What is the purpose of this research study?

The purpose of this research study is to better understand how your body responds (through changes in heart rate, sweating and muscle movements, for example) to seeing another person's emotions or seeing another person in pain. Specifically, we wanted to see whether people with autism spectrum disorder respond in the same way or differently to emotional stimuli.

5. What was done during this research study?

This study required you to take part in three research sessions. During this study, you were required to watch people in physical pain (for example, being stabbed by a needle) or emotional distress. Your physiological response to these stimuli was assessed through the collection of self-report data, and through measurement of heart rate, skin conductance, and muscle movement.

6. Was any deception used in this research study?

We said that you were watching videos of patients undergoing painful medical treatment. However, the people you saw were student actors, and were not in any pain. Similarly, the videos you saw of people in emotional distress, all contained actors. Lastly, you witnessed to an altercation between the researcher and a "research assistant". This was part of the experiment, and everything was staged. Anything that you said or did during the sessions will be kept completely confidential.

You were also told that the recording disks on your face measured sweating (skin conductance). These recording disks actually measure muscle reactivity to the videos. You were not told this beforehand, in case the knowledge of being recorded changed your reactions to the videos.

7. Is anything further required of you?

Please do not disclose anything that happened during this research session to anyone else, as this may bias future participants and their performance.

If you are still feeling stressed at the end of the research study, we can provide contact details of a clinical psychologist who can assist you.

Signatures

As a representative of this study, I have explained to the participant, in detail, the purpose, the procedures, and any deception used in this research study.

_____ _____

Signature of Person Obtaining Consent and Authorization Date

You have been informed, in detail, about this study's purpose, procedures, and deceptions. You have been given the opportunity to ask questions before you sign. By signing this form, you are not waiving any of your legal rights.

_____ _____

Signature of Person Consenting and Authorizing Date

APPENDIX G

LIST OF STATISTICAL PACKAGES USED

Package	Version	Reference
car	2.1-2	(Fox & Weisberg, 2011)
cowplot	0.6.2	(Wilke, 2016)
dplyr	0.5.0	(Wickham & Francois, 2016)
coefplot2	0.1.3.2	(Bolker & Su, 2011)
effsize	0.6.4	(Torchiano, 2016)
ggplot2	2.1.0	(Wickham, 2009)
Hmisc	3.17-4	(Harrell & Alzola, 2006)
knitr	1.13	(Xie, 2015)
lattice	0.20-33	(Sarkar, 2008)
lavaan	0.5-20	(Rosseel, 2012)
lme4	1.1-12	(Bates, Maechler, Bolker, & Walker, 2015)
lmerTest	2.0-32	(Kuznetsova et al., 2015)
multcomp	1.4-6	(Hothorn et al., 2008)
MuMIn	1.15.6	(Bartoń, 2016)
nlme	3.1-124	(Pinheiro et al., 2016)
pacman	0.4.1	(Rinker & Kurkiewicz, 2015)
plyr	1.8.4	(Wickham, 2011)
psych	1.6.6	(Revelle, 2015)
reshape2	1.4.1	(Wickham, 2007)
sjPlot	2.0.2	(Lüdecke, 2016)
tidyr	0.6.0	(Wickham, 2016)

APPENDIX H

AUTISM SPECTRUM QUOTIENT

The Autistic-Spectrum Quotient

1. I prefer to do things with others rather than on my own.	definitely agree	slightly agree	slightly disagree	definitely disagree
2. I prefer to do things the same way over and over again.	definitely agree	slightly agree	slightly disagree	definitely disagree
3. If I try to imagine something, I find it very easy to create a picture in my mind.	definitely agree	slightly agree	slightly disagree	definitely disagree
4. I frequently get so strongly absorbed in one thing that I lose sight of other things.	definitely agree	slightly agree	slightly disagree	definitely disagree
5. I often notice small sounds when others do not.	definitely agree	slightly agree	slightly disagree	definitely disagree
6. I usually notice car number plates or similar strings of information.	definitely agree	slightly agree	slightly disagree	definitely disagree
7. Other people frequently tell me that what I've said is impolite, even though I think it is polite.	definitely agree	slightly agree	slightly disagree	definitely disagree
8. When I'm reading a story, I can easily imagine what the characters might look like.	definitely agree	slightly agree	slightly disagree	definitely disagree
9. I am fascinated by dates.	definitely agree	slightly agree	slightly disagree	definitely disagree
10. In a social group, I can easily keep track of several different people's conversations.	definitely agree	slightly agree	slightly disagree	definitely disagree
11. I find social situations easy.	definitely agree	slightly agree	slightly disagree	definitely disagree
12. I tend to notice details that others do not.	definitely agree	slightly agree	slightly disagree	definitely disagree
13. I would rather go to a library than a party.	definitely agree	slightly agree	slightly disagree	definitely disagree
14. I find making up stories easy.	definitely agree	slightly agree	slightly disagree	definitely disagree
15. I find myself drawn more strongly to people than to things.	definitely agree	slightly agree	slightly disagree	definitely disagree
16. I tend to have very strong interests, which I get upset about if I can't pursue.	definitely agree	slightly agree	slightly disagree	definitely disagree
17. I enjoy social chit-chat.	definitely agree	slightly agree	slightly disagree	definitely disagree
18. When I talk, it isn't always easy for others to get a word in edgeways.	definitely agree	slightly agree	slightly disagree	definitely disagree
19. I am fascinated by numbers.	definitely agree	slightly agree	slightly disagree	definitely disagree
20. When I'm reading a story, I find it difficult to work out the characters' intentions.	definitely agree	slightly agree	slightly disagree	definitely disagree
21. I don't particularly enjoy reading fiction.	definitely agree	slightly agree	slightly disagree	definitely disagree
22. I find it hard to make new friends.	definitely agree	slightly agree	slightly disagree	definitely disagree
23. I notice patterns in things all the time.	definitely agree	slightly agree	slightly disagree	definitely disagree
24. I would rather go to the theatre than a museum.	definitely agree	slightly agree	slightly disagree	definitely disagree
25. It does not upset me if my daily routine is distubed.	definitely agree	slightly agree	slightly disagree	definitely disagree
26. I frequently find that I don't know how to keep a conversation going.	definitely agree	slightly agree	slightly disagree	definitely disagree

27. I find it easy to "read between the lines" when someone is talking to me.	definitely agree	slightly agree	slightly disagree	definitely disagree
28. I usually concentrate more on the whole picture, rather than the small details.	definitely agree	slightly agree	slightly disagree	definitely disagree
29. I am not very good at remembering phone numbers.	definitely agree	slightly agree	slightly disagree	definitely disagree
30. I don't usually notice small changes in a situation, or a person's appearance.	definitely agree	slightly agree	slightly disagree	definitely disagree
31. I know how to tell if someone listening to me is getting bored.	definitely agree	slightly agree	slightly disagree	definitely disagree
32. I find it easy to do more than one thing at once.	definitely agree	slightly agree	slightly disagree	definitely disagree
33. When I talk on the phone, I'm not sure when it's my turn to speak.	definitely agree	slightly agree	slightly disagree	definitely disagree
34. I enjoy doing things spontaneously.	definitely agree	slightly agree	slightly disagree	definitely disagree
35. I am often the last to understand the point of a joke.	definitely agree	slightly agree	slightly disagree	definitely disagree
36. I find it easy to work out what someone is thinking or feeling just by looking at their face.	definitely agree	slightly agree	slightly disagree	definitely disagree
37. If there is an interruption, I can switch back to what I was doing very quickly.	definitely agree	slightly agree	slightly disagree	definitely disagree
38. I am good at social chit-chat.	definitely agree	slightly agree	slightly disagree	definitely disagree
39. People often tell me that I keep going on and on about the same thing.	definitely agree	slightly agree	slightly disagree	definitely disagree
40. When I was young, I used to enjoy playing games involving pretending with other children.	definitely agree	slightly agree	slightly disagree	definitely disagree
41. I like to collect information about categories of things (e.g. types of car, types of bird, types of train, types of plant, etc.).	definitely agree	slightly agree	slightly disagree	definitely disagree
42. I find it difficult to imagine what it would be like to be someone else.	definitely agree	slightly agree	slightly disagree	definitely disagree
43. I like to plan any activities I participate in carefully.	definitely agree	slightly agree	slightly disagree	definitely disagree
44. I enjoy social occasions.	definitely agree	slightly agree	slightly disagree	definitely disagree
45. I find it difficult to work out people's intentions.	definitely agree	slightly agree	slightly disagree	definitely disagree
46. New situations make me anxious.	definitely agree	slightly agree	slightly disagree	definitely disagree
47. I enjoy meeting new people.	definitely agree	slightly agree	slightly disagree	definitely disagree
48. I am a good diplomat.	definitely agree	slightly agree	slightly disagree	definitely disagree
49. I am not very good at remembering people's date of birth.	definitely agree	slightly agree	slightly disagree	definitely disagree
50. I find it very easy to play games with children that involve pretending.	definitely agree	slightly agree	slightly disagree	definitely disagree

APPENDIX I

INTERPERSONAL REACTIVITY INDEX

The following statements inquire about your thoughts and feelings in a variety of situations. For each item, indicate how well it describes you by choosing the appropriate letter on the scale at the top of the page: A, B, C, D, or E. When you have decided on your answer, fill in the letter on the answer sheet next to the item number. READ EACH ITEM CAREFULLY BEFORE RESPONDING. Answer as honestly as you can. Thank you.

ANSWER SCALE:

A	B	C	D	E
DOES NOT DESCRIBE ME WELL				DESCRIBES ME VERY WELL

1. I daydream and fantasize, with some regularity, about things that might happen to me. (FS)
2. I often have tender, concerned feelings for people less fortunate than me. (EC)
3. I sometimes find it difficult to see things from the "other guy's" point of view. (PT) (-)
4. Sometimes I don't feel very sorry for other people when they are having problems. (EC)(-)
5. I really get involved with the feelings of the characters in a novel. (FS)
6. In emergency situations, I feel apprehensive and ill-at-ease. (PD)
7. I am usually objective when I watch a movie or play, and I don't often get completely

caught up in it. (FS) (-)

8. I try to look at everybody's side of a disagreement before I make a decision. (PT)

9. When I see someone being taken advantage of, I feel kind of protective towards them. (EC)

10. I sometimes feel helpless when I am in the middle of a very emotional situation. (PD)

11. I sometimes try to understand my friends better by imagining how things look from their perspective. (PT)

12. Becoming extremely involved in a good book or movie is somewhat rare for me. (FS) (-)

13. When I see someone get hurt, I tend to remain calm. (PD) (-)

14. Other people's misfortunes do not usually disturb me a great deal. (EC) (-)

15. If I'm sure I'm right about something, I don't waste much time listening to other people's arguments. (PT) (-)

16. After seeing a play or movie, I have felt as though I were one of the characters. (FS)

17. Being in a tense emotional situation scares me. (PD)

18. When I see someone being treated unfairly, I sometimes don't feel very much pity for them.

(EC) (-)

19. I am usually pretty effective in dealing with emergencies. (PD) (-)

20. I am often quite touched by things that I see happen. (EC)

21. I believe that there are two sides to every question and try to look at them both. (PT)

22. I would describe myself as a pretty soft-hearted person. (EC)

23. When I watch a good movie, I can very easily put myself in the place of a leading character. (FS)

24. I tend to lose control during emergencies. (PD)

25. When I'm upset at someone, I usually try to "put myself in his shoes" for a while. (PT)

26. When I am reading an interesting story or novel, I imagine how I would feel if the events in the story were happening to me. (FS)

27. When I see someone who badly needs help in an emergency, I go to pieces. (PD)

28. Before criticizing somebody, I try to imagine how I would feel if I were in their place. (PT)

NOTE:(-) denotes item to be scored in reverse fashion

PT = perspective-taking scale

FS = fantasy scale

EC = empathic concern scale

PD = personal distress scale

APPENDIX J

EMOTIONAL CONTAGION SCALE

The Emotional Contagion (EC) Scale

1 If someone I'm talking with begins to cry, I get teary-eyed.
2 Being with a happy person picks me up when I'm feeling down.
3 When someone smiles warmly at me, I smile back and feel warm inside.
4 I get filled with sorrow when people talk about the death of their loved ones.
5 I clench my jaws and my shoulders get tight when I see the angry faces on the news.
6 When I look into the eyes of the one I love, my mind is filled with thoughts of romance.
7 It irritates me to be around angry people.
8 Watching the fearful faces of victims on the news makes me try to imagine how they might be feeling.
9 I melt when the one I love holds me close.
10 I tense when overhearing an angry quarrel.
11 Being around happy people fills my mind with happy thoughts.
12 I sense my body responding when the one I love touches me.
13 I notice myself getting tense when I'm around people who are stressed out.
14 I cry at sad movies.
15 Listening to the shrill screams of a terrified child in a dentist's waiting room makes me feel nervous.

APPENDIX K

INTERNAL CONSISTENCY AND CONFIRMATORY FACTOR ANALYSIS OF EMPATHY SCALES

Items on the Emotional Contagion Scale and Interpersonal Reactivity Index were divided into affective empathy, cognitive empathy and self-regulation scales. The list of items and their correlations with other items on the scales are given in the tables below.

Table 34

Reliability Analysis of Affective Empathy Items

		α			*r*				
Item		Raw	*SE*	*S/ N*	Ave	Raw	Cor	*M*	*SD*
IRI2	tender, concerned feelings for the less fortunate	0.90	0.02	9.15	.28	.67	.67	2.47	1.15
IRI4[a]	sometimes don't feel very sorry for people having problems	0.90	0.02	9.58	.29	.50	.48	2.35	1.33
IRI5	get involved with feelings of characters in a novel	0.90	0.02	9.64	.30	.50	.46	1.94	1.32
IRI7[a]	objective when watching a movie / play; not caught up in it	0.91	0.02	9.81	.30	.42	.38	2.09	1.27
IRI9	feel protective towards people being taken advantage of	0.90	0.02	9.60	.29	.49	.47	2.96	1.03
IRI13[a]	remain calm when seeing someone get hurt	0.90	0.02	9.46	.29	.56	.53	1.98	1.27
IRI14[a]	not disturbed by others' misfortunes	0.90	0.02	9.00	.28	.74	.74	2.49	1.18
IRI16	felt like one of the characters after seeing a play / movie	0.90	0.02	9.43	.29	.58	.55	1.89	1.32
IRI18[a]	doesn't feel pity for someone treated unfairly	0.91	0.02	9.78	.30	.42	.39	2.98	1.16

Table 34 (cont.)

IRI20	touched by things that I see happen	0.90	0.02	8.94	.28	.76	.76	2.51	1.08
IRI22	soft-hearted person	0.90	0.02	9.32	.29	.61	.59	2.27	1.28
IRI23	can easily put self in the place of a leading character in movie	0.90	0.02	9.42	.29	.57	.55	2.27	1.28
IRI26	when reading a story, I imagine how I would feel if events were happening to me	0.90	0.02	9.67	.30	.48	.45	2.31	1.33
ECS1	get teary eyed when someone cries	0.90	0.02	9.13	.28	.68	.68	1.45	1.08
ECS2	being with happy person picks me up	0.90	0.02	9.46	.29	.54	.54	2.47	1.09
ECS3	smile back at someone smiling and feel warm inside	0.90	0.02	9.15	.28	.67	.67	2.84	1.09
ECS4	filled with sorrow when people talk about death	0.90	0.02	8.96	.28	.75	.75	2.29	1.14
ECS5	clench jaws and tighten shoulders when seeing angry faces	0.90	0.02	9.66	.30	.46	.44	1.15	1.05
ECS6	looking into eyes of loved one, mind is filled with romance	0.90	0.02	9.52	.29	.52	.52	2.51	1.10
ECS9	melt when one I love holds me	0.90	0.02	9.65	.30	.47	.46	2.44	1.21
ECS10	tense when overhearing quarrel	0.91	0.02	9.82	.30	.40	.38	2.21	1.21
ECS11	being around happy people fills mind with happy thoughts	0.90	0.02	9.19	.29	.65	.65	2.63	1.04
ECS12	my body responds when one I love touches me	0.90	0.02	9.60	.29	.48	.47	2.83	1.01
ECS14	cry at sad movies	0.90	0.02	9.26	.29	.64	.62	1.81	1.41

Note. S/N = signal to noise ratio; r_{ave} = average inter-item correlation; r_{raw} = correlation of each item with the total score, not corrected for item overlap; r_{cor} = item whole correlation corrected for item overlap and scale reliability. IRI = Interpersonal Reactivity Index; ECS = Emotional Contagion Scale.

[a] Negatively keyed item.

Table 35

Reliability Analysis of Cognitive Empathy Items

Item		α			*r*				
		Raw	*SE*	*S/ N*	Ave	Raw	Cor	*M*	*SD*
IRI3	try to look at everybody's side of a disagreement	0.72	0.07	2.61	.30	.49	.31	2.73	1.20
IRI8 [a]	difficult to see things from other guy's viewpoint	0.69	0.07	2.29	.28	.56	.48	2.67	1.14
IRI11	try to understand friends better by imagining their perspective	0.65	0.08	1.89	.24	.71	.63	2.48	1.20
IRI21	believe there are two sides to every question and try to look at them both	0.67	0.07	2.08	.26	.63	.57	2.81	1.12
IRI25	when upset at someone, I try to put myself in his shoes	0.67	0.07	2.03	.25	.65	.58	1.61	1.16
IRI28	before criticizing somebody, I imagine how I would feel	0.63	0.08	1.75	.23	.75	.73	2.00	1.12
ECS8	seeing fearful faces makes me try to imagine how they are feeling	0.72	0.07	2.63	.30	.48	.35	2.20	1.22

Note. IRI = Interpersonal Reactivity Index; ECS = Emotional Contagion Scale.

[a] Negatively keyed item.

Table 36

Reliability Analysis of Self-Regulation Items

Item		α			*r*				
		Raw	*SE*	*S/ N*	Ave	Raw	Cor	*M*	*SD*
IRI6 [a]	feel apprehensive and ill-at-ease in emergencies	0.78	0.05	3.58	.34	.68	.62	1.87	1.23
IRI10 [a]	feel helpless in an emotional situation	0.81	0.05	4.36	.38	.49	.38	2.43	1.10
IRI13	remain calm when seeing someone get hurt	0.78	0.05	3.68	.34	.66	.59	1.98	1.27
IRI17 [a]	tense emotional situations scare me	0.78	0.05	3.61	.34	.69	.62	2.14	1.36
IRI24 [a]	lose control during emergencies	0.77	0.06	3.34	.32	.71	.71	0.97	0.93
IRI19	effective in dealing with emergencies	0.79	0.05	3.77	.35	.61	.57	1.57	1.09
IRI27 [a]	go to pieces when seeing someone who needs help in emergency	0.77	0.06	3.51	.33	.70	.65	1.12	1.25
ECS15 [a]	listening to child's screams at dentist makes me nervous	0.78	0.05	3.69	.35	.67	.59	1.67	1.34

Note. IRI = Interpersonal Reactivity Index; ECS = Emotional Contagion Scale.

[a] Negatively keyed item.

Confirmatory Factor Analysis

I ran a confirmatory factor analysis on the full online sample, using the package `lavaan` (Rosseel, 2012), to predict cognitive empathy, affective empathy and self-regulation from the items listed in the tables above. maximum likelihood modelling was used. The assumption of multivariate normality was checked beforehand. Missing data (n = 2) were excluded listwise.

One thousand bootstrapped samples were used to test the maximum likelihood estimates model. The model converged normally after 47 iterations. The model performed significantly better than the null model, χ^2 (703) = 3351.98, $p \leq .0001$, though it still performed significantly worse than the over-identified model, χ^2 (661) = 7862.72, $p \leq .0001$. The relative and absolute fit indices did not meet the recommended cut-offs of .95 and .05, respectively (Hu & Bentler, 1999; Kline, 2010). However, the root mean squared error of approximation (RMSEA) and standardised root mean squared error of approximation (SRMR) did meet Bentler and Bonnet's (1980) cut-off of .1, and the standard errors were suitable for the estimate size. Additionally, all items were significantly correlated with their latent variable (see Table 38 and Table 39).

Table 37

Confirmatory Factor Analysis Fit Indices

Index	Estimate		
Relative fit indices (compared to null model)			
Comparative Fit Index (CFI)	.624		
Tucker-Lewis Index (TLI)	.600		
Absolute fit indices		95% CI	Significance
RMSEA	.089	[.086, .092]	≤ .0001
SRMR	.095		

Note. RMSEA = Root mean squared error of approximation; SRMSEA = Square root mean squared error of approximation.

Table 38

Standardised Coefficients: Affective Empathy

	Estimate	Standard error	Z-value	Significance
IRI2	1			
IRI4	0.88	0.08	10.85	≤ .0001
IRI5	0.89	0.09	10.07	≤ .0001
IRI7	0.69	0.08	8.29	≤ .0001
IRI9	0.65	0.07	9.95	≤ .0001
IRI13	0.56	0.09	6.63	≤ .0001
IRI14	1.02	0.08	12.32	≤ .0001
IRI16	0.86	0.09	9.67	≤ .0001
IRI18	0.68	0.07	10.13	≤ .0001
IRI20	1.05	0.08	13.56	≤ .0001
IRI22	0.94	0.08	11.63	≤ .0001
IRI23	0.90	0.08	10.67	≤ .0001
IRI26	0.85	0.09	9.87	≤ .0001
ECS1	1.00	0.08	12.40	≤ .0001
ECS2	0.67	0.07	10.32	≤ .0001
ECS3	0.71	0.06	11.43	≤ .0001
ECS4	1.11	0.09	12.81	≤ .0001
ECS5	0.61	0.07	8.58	≤ .0001
ECS6	0.73	0.07	9.83	≤ .0001
ECS9	0.81	0.08	10.49	≤ .0001
ECS10	0.73	0.08	9.14	≤ .0001
ECS11	0.71	0.07	10.74	≤ .0001
ECS12	0.66	0.07	9.85	≤ .0001
ECS14	1.01	0.09	10.87	≤ .0001

Note. IRI = Interpersonal Reactivity Index; ECS = Emotional Contagion Scale.

Table 39

Standardised Coefficients: Cognitive Empathy and Self-Regulation

	Estimate	Standard error	Z-value	Significance
Cognitive empathy				
IRI3	1			
IRI8	1.18	0.18	6.37	≤ .0001
IRI11	1.96	0.27	7.30	≤ .0001
IRI21	1.51	0.22	6.93	≤ .0001
IRI25	1.78	0.25	7.06	≤ .0001
IRI28	1.90	0.26	7.26	≤ .0001
ECS8	1.60	0.24	6.80	≤ .0001
Self-regulation				
IRI6	1			
IRI10	0.65	0.09	7.46	≤ .0001
IRI13	0.45	0.09	5.09	≤ .0001
IRI17	0.89	0.10	9.15	≤ .0001
IRI24	0.85	0.08	10.46	≤ .0001
IRI19	0.69	0.08	8.62	≤ .0001
IRI27	1.00	0.10	10.43	≤ .0001
ECS15	0.69	0.10	7.03	≤ .0001

Note. IRI = Interpersonal Reactivity Index; ECS = Emotional Contagion Scale.

Given the significant item-latent variable correlations and good-to-excellent internal consistency in all three factors (see Table 34 - Table 36), it can be concluded that the model performed adequately, though there is room for improvement. The realtively poor model performance may be due to measurement error on the items. As it is not recommended to perform extensive post hoc modification to a CFA model unless there are strong theoretical reasons to do so (Kline, 2010), the model was not modified. As expected, the cognitive and affective empathy facets covaried significantly (see Table 40), though cognitive empathy and self-regulation did not.

Table 40

Empathy Facet Covariance

Covariances	Estimate	Standard Error	Z-value	Significance
Affective empathy ~				
Cognitive empathy	.65	.09	7.46	≤ .0001
Self-regulation	.45	.09	5.09	≤ .0001
Cognitive empathy ~				
Self-regulation	.02	0.02	1.21	0.225

APPENDIX L

TORONTO ALEXITHYMIA SCALE

Difficulty Identifying Feelings

1. I am often confused about what emotion I am feeling.
3. I have physical sensations that even doctors don't understand.
6. When I am upset, I don't know if I am sad, frightened or angry.
7. I am often puzzled by sensation in my body.
9. I have feelings that I can't quite identify.
13. I don't know what's going on inside me.
14. I often don't know why I am angry.

Difficulty Describing Feelings

2. It is difficult for me to find the right words for my feelings.
4. I am able to describe my feelings easily.
11. I find it hard to describe how I feel about people.
12. People tell me to describe feelings more.
17. It is difficult for me to reveal my innermost feelings, even to close friends.

Externally-Oriented Thinking

5. I prefer to analyse problems rather than just describe them.
8. I prefer to just let things happen rather than to understand why they turned out that way.
10. Being in touch with emotions is essential.
15. I prefer talking to people about their daily activities rather than their feelings.
16. I prefer to watch "light" entertainment shows rather than psychological dramas.
18. I can feel close to someone, even in moments of silence.
19. I find examination of my feelings useful in solving personal problems.
20. Looking for hidden meanings in movies or plays distracts for their enjoyment.

Note. Items 4, 5, 10, 18 and 19 are negatively keyed.

APPENDIX M

SURVEY MONKEY QUESTIONNAIRE

Response to emotions in autism

Welcome!

THANK YOU FOR PARTICIPATING IN THIS STUDY. WE APPRECIATE YOUR TIME AND ASSISTANCE!

INFORMATION:

This study looks at how your body responds (through changes in heart rate and skin conductance, for example) to seeing another person's emotions or seeing another person in pain. We would like to see whether people with Autism Spectrum Disorder (ASD) respond the same as or different to neurotypical individuals. The information from this study may help improve our understanding of how people with ASD perceive and experience other people's emotions, specifically with regard to painful experiences.

PROCEDURE:

If you consent to participating in this study, you will be asked to come to the Department of Psychology for 3 sessions. The first session will be an interactive session at the Child Guidance Clinic to get to know you. This session will take approximately one hour. The next two sessions will be held in the Psychology Department lab and will approximately 2 hours long (each). You will be shown short video clips of people in physically painful or emotionally distressing situations. You will also be shown videos of people experiencing various emotions. During the videos, heart rate and sweating will be measured using small recording discs. There are no risks involved in the procedure. Participation is voluntary.

The first session will be video-taped for diagnostic purposes. Only a small group of relevant clinicians will be able to see the video in order to make a diagnosis of autism spectrum disorder (or not on the spectrum).

Risks, Discomforts & Inconveniences

Participants will be required to wear small recording discs on their chest, face and hands to measure bodily responses. You may find this uncomfortable. However, the recording discs are not harmful in any way. You will also be asked to watch videos of people in physically painful or emotionally distressing situations. If you think that this footage might be upsetting to you, you are under no obligation to participate. Also, if you participate and find any of the procedures uncomfortable at any time during the experiment, you are free to discontinue participation without penalty.

Privacy and Confidentiality

We will take strict precautions throughout the study to keep your personal information safe and confidential. Your information will be kept without your name or other personal identifiers, only a code, in a locked file cabinet or on a password-protected, secure computer. Only certain people have the right to review these research records. These people include the researchers for this study and certain University of Cape Town officials. The data gathered from this research may be published, but your contribution will remain anonymous.

Only a small group of relevant clinicians will be able to see the recorded video of session 1 in order to make a diagnosis of autism spectrum disorder (or not on the spectrum). The videos will be kept in a locked filing cabinet and will be destroyed afterwards. The videos will not be published.

Money Matters

If you have been recruited through the Student Research Participation Programme (SRPP), you will receive 10 SRPP points upon completion of the study. If you have been recruited outside of the SRPP system, you will receive R100 for participation in the study.

VOLUNTARY PARTICIPATION

Your participation is entirely voluntary, and you may withdraw from the study at any time. This means that you are not obligated to participate in the study, even if you indicate that you are available below.

QUESTIONS AND CONTACTS

If you have any questions, you can e-mail Michelle Hoogenhout at michellehoog@gmail.com. The study is conducted under the supervision of Dr Susan Malcolm-Smith.

Response to emotions in autism

Eligibility

WHO CAN PARTICIPATE IN THIS STUDY?

* 1. Are you between the ages of 14 and 45?

- ◯ Yes, I am between the ages of 14 and 45
- ◯ No, I am not between the ages of 14 and 45

* 2. Are you fluent in English?

- ◯ Yes, I am fluent in English
- ◯ No, I am not fluent in English

If you answered 'YES' to the previous questions, you are eligible to participate in this study.

* 3. Have you ever had a heart condition or are you currently on medication affecting you blood circulation?

- ◯ Yes, I have had a heart condition or I am on medication that affects my blood circulation
- ◯ No, I do not take heart medication or I am not on medication that affects my blood circulation

If you answered 'NO' to the question above, you are eligible to participate in this study

If you met the requirements for the above study and wish to be considered for participation in the physiological part of the study, please fill in your contact details on the next page and complete the rest of the survey in full.

If you are not interested, or do not meet our study requirements (as listed above), please simply log off.

Response to emotions in autism

Consent and contact information

* 1. Contact Information (so that we may contact you for the lab-based part of this study)

Name

Email Address

Phone number

2. Student number (optional - to award SRPP points)

Informed Consent

* 3. I have read the information on the previous pages, my questions have been answered, and I consent voluntarily to participate in this study.

- ◯ Yes, I consent
- ◯ No, I do not consent

* 4. Would you like to be notified of future research projects conducted by our research group?

- ◯ Yes
- ◯ No

Response to emotions in autism

Tell us about yourself

Although some of these questions are of a personal nature, please try to answer as honestly as you can. Your answers will be kept confidential.

A. Personal Information:

* 1. Age

* 2. Gender

* 3. Race

- White
- Black
- Coloured
- Indian
- Asian

Other (please specify)

* 4. Handedness

The next section will ask about mental and physical health. Please answer all the questions as honestly as possible. All answers are confidential and will not be disclosed to anyone.

* 5. Please answer yes or no to the following questions. If you have an autism spectrum disorder, do not include it here. You will be asked about this separately.

Do you currently have or have you ever had...

	Yes	No
Problems with vision (if you wear glasses but can see, answer 'no')	◯	◯
Problems with hearing	◯	◯
Epilepsy	◯	◯
Cerebral palsy	◯	◯
Encephalitis/ Meningitis (inflammation of the brain or its membranes)	◯	◯
Hydrocephalus (water on the brain)	◯	◯
Traumatic brain injury	◯	◯
Brain tumour	◯	◯
Stroke	◯	◯
Tourette's syndrome	◯	◯
Major Depression	◯	◯
Attention-deficit / hyperactivity disorder (ADD/ ADHD)	◯	◯
Anxiety Disorder	◯	◯
Bipolar Disorder	◯	◯
Obsessive/Compulsive Disorder	◯	◯
Post-traumatic Stress Disorder	◯	◯
Schizophrenia	◯	◯
Dyslexia	◯	◯
Substance Abuse Disorder	◯	◯
Rett's syndrome	◯	◯
Tuberous Sclerosis	◯	◯
Fragile X Syndrome	◯	◯

Other neurological or mental health problem (excluding ASD) – please specify

6. If you have Major Depression, are you currently depressed?

◯ Yes

◯ No

* 7. Are you currently taking any prescription medication?

- ◯ Yes
- ◯ No

If yes, what medication(s)

* 8. Are you currently using any other drugs?

- ◯ Yes
- ◯ No

* 9. Have you been diagnosed with, or do you suspect that you have, an autism spectrum disorder/ Asperger's Syndrome?

- ◯ I have been diagnosed with ASD
- ◯ I suspect that I have ASD
- ◯ No, I do not have ASD

Response to emotions in autism

* 1. Please indicate how strongly you agree with each of the following statements. Some statements may apply more than others. Answer quickly and honestly.

	Definitely Agree	Slightly Agree	Slightly Disagree	Definitely Disagree
I prefer to do things with others rather than on my own.	○	○	○	○
I prefer to do things the same way over and over again.	○	○	○	○
If I try to imagine something, I find it very easy to create a picture in my mind.	○	○	○	○
I frequently get so strongly absorbed in one thing that I lose sight of other things.	○	○	○	○
I often notice small sounds when others do not.	○	○	○	○
I usually notice car number plates or similar strings of information.	○	○	○	○
Other people frequently tell me that what I've said is impolite, even though I think it is polite.	○	○	○	○
When I'm reading a story, I can easily imagine what the characters might look like.	○	○	○	○
I am fascinated by dates.	○	○	○	○
In a social group, I can easily keep track of several different people's conversations.	○	○	○	○
I find social situations easy.	○	○	○	○
I tend to notice details that others do not.	○	○	○	○
I would rather go to a library than a party.	○	○	○	○
I find making up stories easy.	○	○	○	○
I find myself drawn more strongly to people than to things.	○	○	○	○
I tend to have very strong interests, which I get upset about if I can't pursue.	○	○	○	○
I enjoy social chit-chat.	○	○	○	○
When I talk, it isn't always easy for others to get a word in edgeways.	○	○	○	○
I am fascinated by numbers.	○	○	○	○
When I'm reading a story, I find it difficult to work out the characters' intentions.	○	○	○	○

	Definitely Agree	Slightly Agree	Slightly Disagree	Definitely Disagree
I don't particularly enjoy reading fiction.	○	○	○	○
I find it hard to make new friends.	○	○	○	○
I notice patterns in things all the time.	○	○	○	○
I would rather go to a theatre than a museum.	○	○	○	○
It does not upset me if my daily routine is disturbed.	○	○	○	○
I frequently find that I don't know how to keep a conversation going.	○	○	○	○
I find it easy to "read between the lines" when someone is talking to me.	○	○	○	○
I usually concentrate more on the whole picture, rather than the small details.	○	○	○	○
I am not very good at remembering phone numbers.	○	○	○	○
I don't usually notice small changes in a situation, or a person's appearance.	○	○	○	○
I know how to tell if someone listening to me is getting bored.	○	○	○	○
I find it easy to do more that one thing at once.	○	○	○	○
When I talk on the phone, I'm not sure when it's my turn to speak.	○	○	○	○
I enjoy doing things spontaneously.	○	○	○	○
I am often the last to understand the point of a joke.	○	○	○	○
I find it easy to work out what someone is thinking or feeling just by looking at their face.	○	○	○	○
If there is an interruption, I can switch back to what I was doing very quickly.	○	○	○	○
I am good at social chit-chat.	○	○	○	○
People often tell me that I keep going on and on about the same thing.	○	○	○	○
When I was young, I used to enjoy playing games involving pretending with other children.	○	○	○	○
I like to collect information about categories of things (e.g. types of car, types of bird, types of train, types of plant, etc.).	○	○	○	○
I find it difficult to imagine what it would be like to be someone else.	○	○	○	○
I like to plan any activities I participate in carefully.	○	○	○	○
I enjoy social occasions.	○	○	○	○
I find it difficult to work out people's intentions.	○	○	○	○
New situations make me anxious.	○	○	○	○
I enjoy meeting new people.	○	○	○	○
I am a good diplomat.	○	○	○	○
I am not very good at remembering people's date of birth.	○	○	○	○
I find it very easy to play games with children that involve pretending.	○	○	○	○

Response to emotions in autism

In the next section rate to what extent the statement applies to you. Some statements may apply more than others. Answer quickly and honestly.

* 1. How often do the following statements apply to you?

Here, "Rarely" means that the statement applies to you about 25% of the time, "Sometimes" means that the statement applies 50% of the time, and "Very Often" means the statement applies about 75% of the time.

	Never	Rarely	Sometimes	Very Often	Always
If someone I'm talking with begins to cry, I get teary-eyed.	○	○	○	○	○
Being with a happy person picks me up when I'm feeling down.	○	○	○	○	○
When someone smiles warmly at me, I smile back and feel warm inside.	○	○	○	○	○
I get filled with sorrow when people talk about the death of their loved ones.	○	○	○	○	○
I clench my jaws and my shoulders get tight when I see the angry faces on the news.	○	○	○	○	○
When I look into the eyes of the one I love, my mind is filled with thoughts of romance.	○	○	○	○	○
It irritates me to be around angry people.	○	○	○	○	○
Watching the fearful faces of victims on the news makes me try to imagine how they might be feeling.	○	○	○	○	○
I melt when the one I love holds me close.	○	○	○	○	○
I tense when overhearing an angry quarrel.	○	○	○	○	○
Being around happy people fills my mind with happy thoughts.	○	○	○	○	○
I sense my body responding when the one I love touches me.	○	○	○	○	○
I notice myself getting tense when I'm around people who are stressed out.	○	○	○	○	○
I cry at sad movies.	○	○	○	○	○
Listening to the shrill screams of a terrified child in a dentist's waiting room makes me feel nervous.	○	○	○	○	○

Response to emotions in autism

The following statements inquire about your thoughts and feelings in a variety of situations.

For each item, indicate how well it describes you by choosing the appropriate statement. When you have decided on your answer, select from the choices next to each item.

Read each item carefully before responding. Answer as honestly as you can.

* 1. How well does the statement describe you?

Does not describe me well = This statement never applies
Describes me a little bit = Applies about 25% of the time
Describes me sometimes = Applies about 50% of the time
Describes me quite well = Applies about 75% of the time
Describes me very well = Applies most (more than 90%) of the time

	Does not describe me well	Describes me a little bit	Describes me sometimes	Describes me quite well	Describes me very well
I daydream and fantasize, with some regularity, about things that might happen to me.	◯	◯	◯	◯	◯
I often have tender, concerned feelings for people less fortunate than me.	◯	◯	◯	◯	◯
I sometimes find it difficult to see things from the "other guy's" point of view.	◯	◯	◯	◯	◯
Sometimes I don't feel very sorry for other people when they are having problems.	◯	◯	◯	◯	◯
I really get involved with the feelings of the characters in a novel.	◯	◯	◯	◯	◯
In emergency situations, I feel apprehensive and ill-at-ease.	◯	◯	◯	◯	◯
I am usually objective when I watch a movie or play, and I don't often get completely caught up in it.	◯	◯	◯	◯	◯
I try to look at everybody's side of a disagreement before I make a decision.	◯	◯	◯	◯	◯
When I see someone being taken advantage of, I feel kind of protective towards them.	◯	◯	◯	◯	◯
I sometimes feel helpless when I am in the middle of a very emotional situation.	◯	◯	◯	◯	◯

	Does not describe me well	Describes me a little bit	Describes me sometimes	Describes me quite well	Describes me very well
I sometimes try to understand my friends better by imagining how things look from their perspective.					
Becoming extremely involved in a good book or movie is somewhat rare for me.					
When I see someone get hurt, I tend to remain calm.					
Other people's misfortunes do not usually disturb me a great deal.					
If I'm sure I'm right about something, I don't waste much time listening to other people's arguments.					
After seeing a play or movie, I have felt as though I were one of the characters.					
Being in a tense emotional situation scares me.					
When I see someone being treated unfairly, I sometimes don't feel very much pity for them.					
I am usually pretty effective in dealing with emergencies.					
I am often quite touched by things that I see happen.					
I believe that there are two sides to every question and try to look at them both.					
I would describe myself as a pretty soft-hearted person.					
When I watch a good movie, I can very easily put myself in the place of a leading character.					
I tend to lose control during emergencies.					
When I'm upset at someone, I usually try to "put myself in his shoes" for a while.					
When I am reading an interesting story or novel, I imagine how I would feel if the events in the story were happening to me.					
When I see someone who badly needs help in an emergency, I go to pieces.					
Before criticizing somebody, I try to imagine how I would feel if I were in their place.					

Response to emotions in autism

* 1. To what extent do you agree with the following questions?

	Strongly disagree	Disagree	Neutral	Agree	Strongly Agree
I am often confused about what emotion I am feeling.	◯	◯	◯	◯	◯
I have physical sensations that even doctors don't understand.	◯	◯	◯	◯	◯
When I am upset, I don't know if I am sad, frightened or angry.	◯	◯	◯	◯	◯
I am often puzzled by sensations in my body.	◯	◯	◯	◯	◯
I have feelings that I can't quite identify.	◯	◯	◯	◯	◯
I don't know what's going on inside me.	◯	◯	◯	◯	◯
I often don't know why I am angry.	◯	◯	◯	◯	◯
I prefer to analyse problems rather than just describe them.	◯	◯	◯	◯	◯
I prefer to just let things happen rather than to understand why they turned out that way.	◯	◯	◯	◯	◯
Being in touch with emotions is essential.	◯	◯	◯	◯	◯
I prefer talking to people about their daily activities rather than their feelings.	◯	◯	◯	◯	◯
I prefer to watch "light" entertainment shows rather than psychological dramas.	◯	◯	◯	◯	◯
I can feel close to someone, even in moments of silence.	◯	◯	◯	◯	◯
I find examination of my feelings useful in solving personal problems.	◯	◯	◯	◯	◯
Looking for hidden meanings in movies or plays distracts for their enjoyment.	◯	◯	◯	◯	◯
It is difficult for me to find the right words for my feelings.	◯	◯	◯	◯	◯
I am able to describe my feelings easily.	◯	◯	◯	◯	◯
I find it hard to describe how I feel about people.	◯	◯	◯	◯	◯
People tell me to describe feelings more.	◯	◯	◯	◯	◯
It is difficult for me to reveal my innermost feelings, even to close friends.	◯	◯	◯	◯	◯

UCT Autism Research

Response to emotions in autism

Thank you for your participation! Your time is appreciated.

You will be contacted soon to arrange a time to come to the Psychology Department ACSENT lab. Feel free to contact Michelle Hoogenhout at michellehoog@gmail.com if you have any questions about your participation in the study.

APPENDIX N

AFFECTIVE STATE QUESTIONS

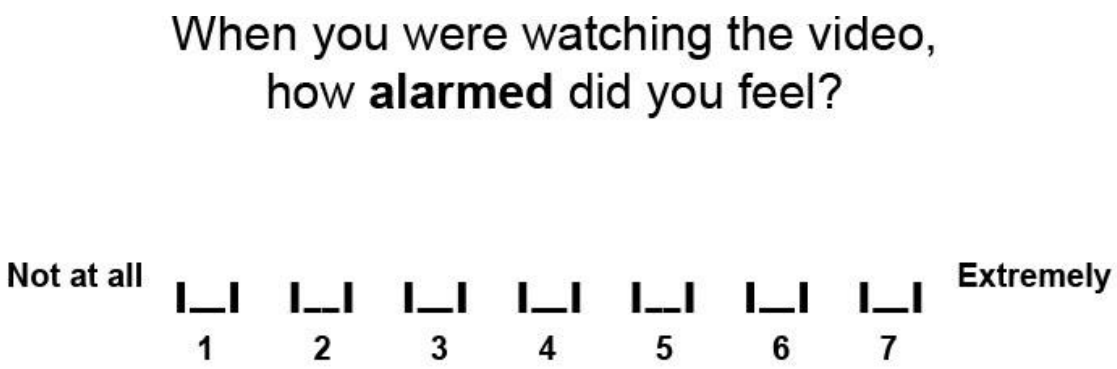

Table 41

List of Empathic Concern and Personal Distress Questions

Empathic concern	Personal distress
Soft-hearted	Alarmed
Compassionate	Distressed
Tender	Disturbed
Moved	Grieved
Sympathetic	Perturbed
	Upset
	Troubled
	Worried

Definitions:

Alarmed: Feeling frightened, disturbed, or in danger

Compassionate: Feeling sympathy and concern for others

Distressed: Suffering from extreme anxiety, sorrow, or pain

Disturbed: Feeling agitated, distressed, unsettled, upset or distraught

Grieved: Feeling intense sorrow

Moved: A strong feeling, especially of sorrow or sympathy, for someone or about something

Perturbed: Feeling anxious or unsettled; upset

Upset: Feeling unhappy, disappointed, or worried

Soft-hearted: Feeling kind and compassionate towards someone/something

Sympathetic: Feeling, showing, or expressing sympathy. Feeling pity or sorrow for someone else's misfortune.

Tender: Feeling gentleness, kindness, and affection

Troubled: Feeling beset by problems; feeling distress or anxiety

Warm-hearted: Feeling sympathetic and kind

Worried: Feeling anxious or troubled about actual or potential problems

APPENDIX O

LIST OF MEDICATIONS

Table 42

List of Medications

Medication	Class	Count
Antidepressants		
Escitalopram	Selective serotonin reuptake inhibitor	1
Fluoxetine	Selective serotonin reuptake inhibitor	1
Antidepressant & other		
Citalopram, amitriptyline, simvastatin	Selective serotonin reuptake inhibitor, tricyclic antidepressant, statin (HMG CoA reductase inhibitor)	1
Citalopram, ziprasidone	Selective serotonin reuptake inhibitor, atypical antipsychotic	1
Amitriptyline, sodium valproate, joint supplement	Tricyclic antidepressant	1
Fluoxetine, contraceptive	Selective serotonin reuptake inhibitor	1
Antidepressant (unspecified), methylphenidate	Antidepressant (unspecified), stimulant	1
Stimulant		
Methylphenidate	Simulant	1
Stimulant & other		
Methylphenidate, risperidone	Simulant, atypical antipsychotic	1
Methylphenidate, antidepressant (unspecified)	Simulant, antidepressant (unspecified)	
Anticonvulsants		
Lamotrigine	Triazine anticonvulsant	1
Phenytoin	Hydantoin anticonvulsant	1
Sodium Valproate	Fatty acid derivative anticonvulsant	1

continued overleaf

Table 42 (cont.)

Antipsychotic		
Risperidone	Atypical antipsychotic	2
Risperidone, methylphenidate	CNS stimulant, atypical antipsychotic	
Ziprasidone, citalopram	Selective serotonin reuptake inhibitor, atypical antipsychotic	
Other		
Antihistamine (unspecified)		2
Antihistamine & asthma medication (unspecified)		1
Contraceptive (unspecified)		2
Statin	HMG CoA reductase inhibitor	2

Note. Medications listed in grey were counted in the category in which they are first listed.

APPENDIX P

ADDITIONAL FIGURES AND TABLES

Study 1

When all participants were included in the analyses of Faux Pas Total and Faux Pas Emotion Recognition scores, Faux Pas control scores significantly predicted both sets of scores. However, as shown in Figure 28 and Figure 29, both the Faux Pas Total and Faux Pas Emotion Recognition model fits were improved by removing two influential cases. The same two cases/participants were removed in both models. The models without the two influential cases were used in the final model, and are presented in Chapter 5, *Faux Pas*, p. 93.

Table 43

Generalised Linear Model Coefficients of Faux Pas Total and Emotion Recognition Scores (with Influential Values)

Fixed effects	β	*SE*	df_{effect}	df_{error}	*F*-value	Probability	
FP Total [a]							
Control Score	7.88	2.38	1	87	23.09	< .001	***
Medication	- 4.92	2.45	1	87	5.05	.027	*
AI	- 4.72	1.41	1	87	11.14	.001	**
FP Emotion Recognition[b]							
Control Score	1.09	0.39	1	87	15.75	< .001	***
Medication	- 0.82	0.47	1	87	4.13	.045	*
AI	- 0.39	0.25	1	87	2.39	.126	

Note. FP = Faux Pas; AI = Autism Index.

[a] variance covariate exponent δ = 0.28, residual *SE* = 9.76 [b] variance covariate exponent δ = 0.22, residual *SE* = 1.76.

* $p < .05$, ** $p < .01$, *** $p < .001$.

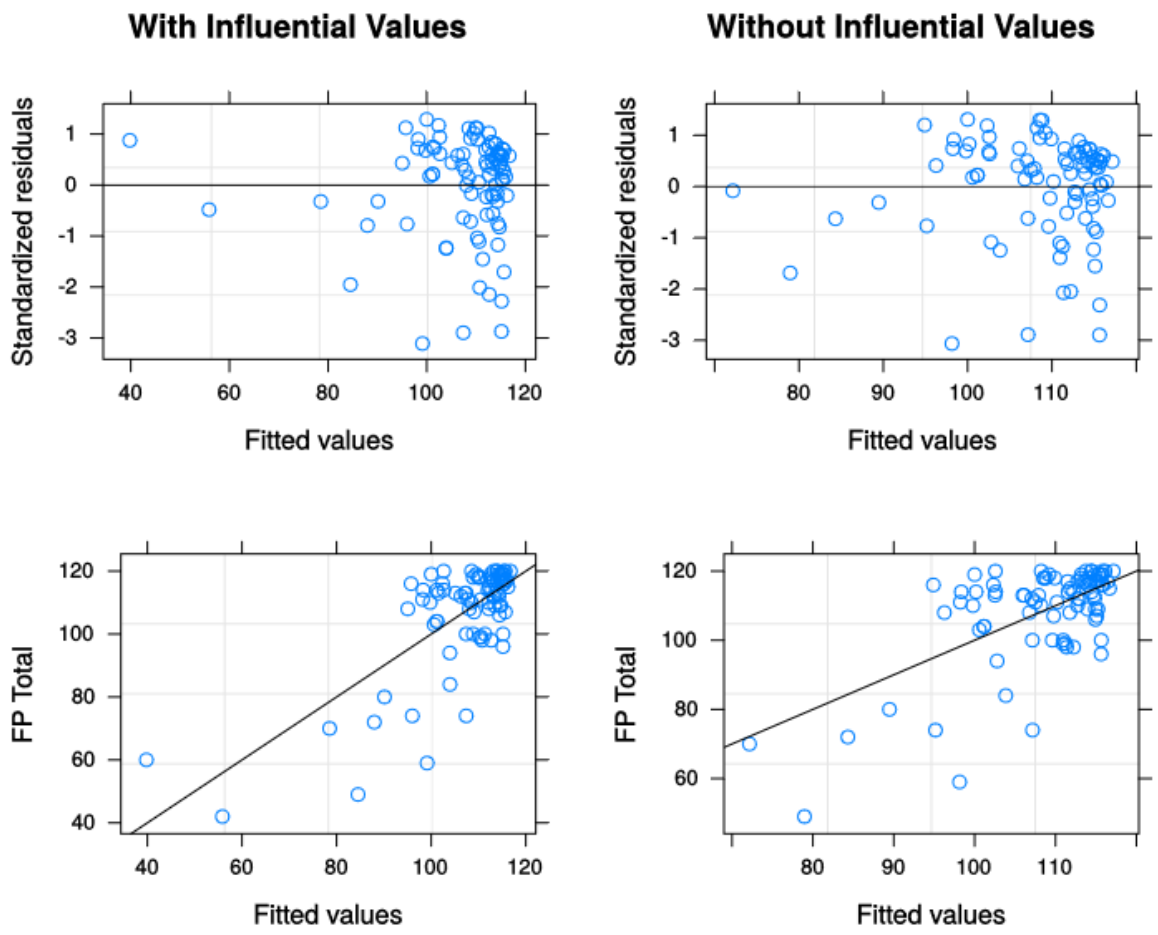

Figure 28. Residual plots of the generalised least squares model predicting Faux Pas (FP) total scores. Two influential cases, with very low predicted values, were removed in the final model, as shown in the plots on the right.

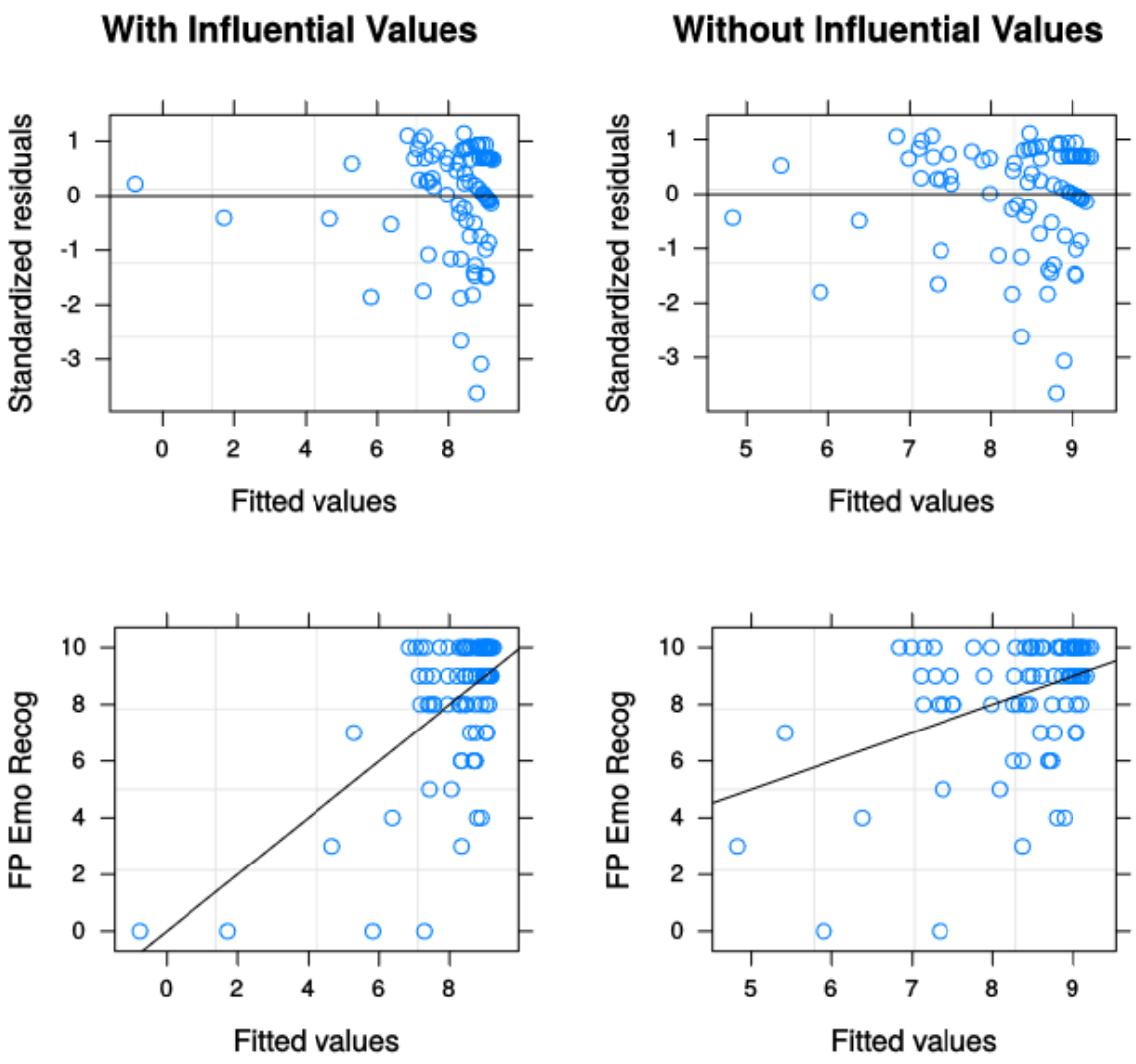

Figure 29. Residual plots of the generalised least squares model predicting Faux Pas emotion recognition (FP Emo Recog) scores. Two influential cases, with very low predicted values, were removed in the final model, as shown in the plots on the right.

Study 3

Muscle Activity

Table 44

Preliminary Random-Effects Muscle Amplitude Model

Fixed effects	df_{effect}	df_{error}	*F*-value	Probability	
Time	1	576	91.93	< .001	***
Condition	1	288	0.18	.670	
Muscle	2	192	0.72	.488	
Time * Condition	1	576	1.63	.202	
Time * Muscle	2	576	4.84	.008	**
Condition * Muscle	2	288	0.07	.933	
Time * Condition * Muscle	2	576	0.45	.638	

Fixed effects	β	*SE*	*df*	*t*-value	Probability	
Time: Pain	0.35	0.08	576	4.12	< .001	***
Condition: Self	- 0.04	0.05	288	- 0.84	.403	
M. corrugator	0.00	0.05	192	- 0.08	.933	
M. orbicularis	0.00	0.05	192	- 0.03	.978	
Time * Condition	0.18	0.13	576	1.35	.176	
Pain * M. corrugator	0.36	0.18	576	2.06	.040	*
Pain * M. orbicularis	0.88	0.42	576	2.08	.038	*
Self condition * M. corrugator	0.02	0.07	288	0.33	.742	
Self condition * M. orbicularis	0.04	0.07	288	0.48	.628	
Pain * Self condition * M. corrugator	- 0.23	0.24	576	- 0.95	.344	
Pain * Self condition * M. orbicularis	- 0.08	0.66	576	- 0.12	.906	

Note. Model 1*:* R^2_M = .65, R^2_C = .65. Number of observations = 1164. Number of groups: ID = 97 (σ^2 = 5.93 x 10^{-20}), muscle in ID = 291 (σ^2 = 2.19 x 10^{-9}), condition in muscle in ID = 582 (σ^2 = 2.44 x 10^{-6}); σ^2_{resid} = 0.34.

*p < .05, **p < .01, ***p < .001.

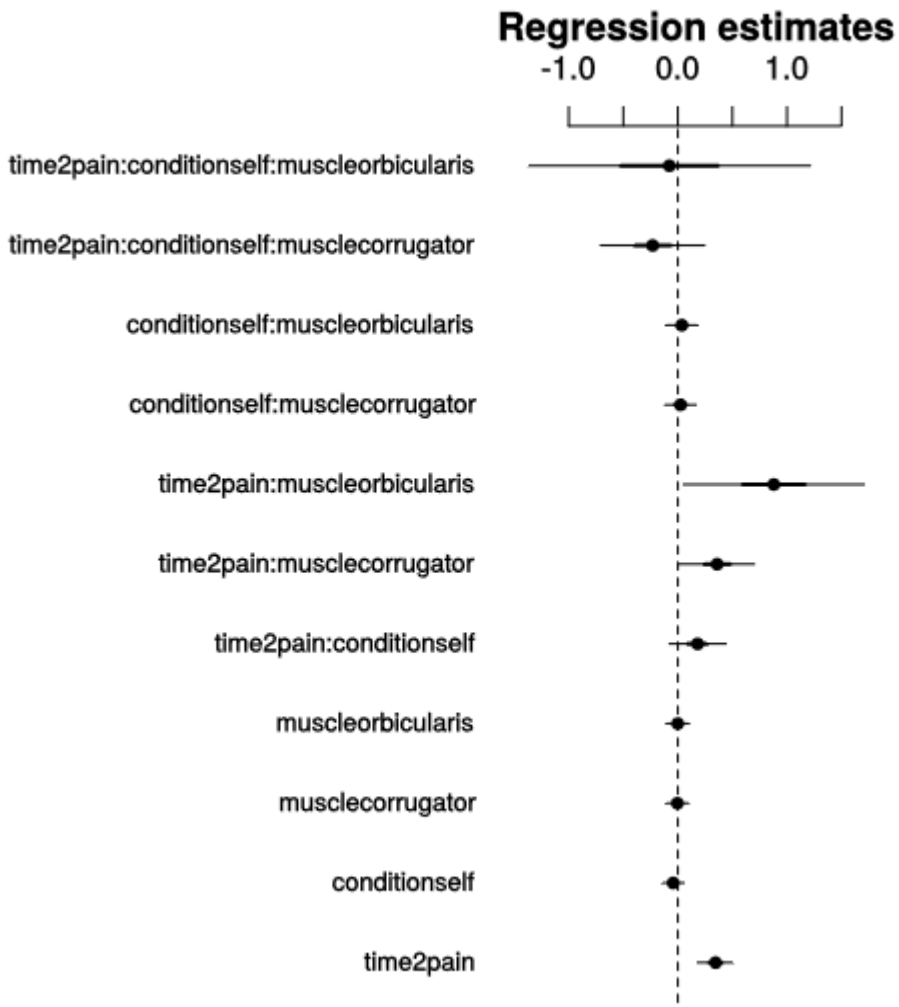

Figure 30. Confidence intervals of the coefficient estimates for the preliminary random-effects model predicting muscle amplitude from time (pain vs. no pain), condition (self vs. other) and muscle (M. orbicularis, M. zygomaticus, M. frontalis).

Table 45

Alternative Mixed-Effects Models of Average Muscle Activity (Square Root Transformed)

Model	Fixed effects	*SS*	*MS*	df_{effect}	df_{error}	*F*-value	Probability	
Model 1	Muscle	0.29	0.15	2	184.00	11.19	< .001	***
	Cycle	0.15	0.15	1	278.00	11.58	.001	**
	AI	0.08	0.08	1	91.00	6.20	.015	*
Model 2	Muscle	0.29	0.15	2	184.00	11.19	< .001	***
	Cycle	0.15	0.15	1	278.00	11.58	.001	**
	Alexithymia	0.05	0.05	1	91.00	4.00	.048	*

Model	Fixed effects	**β**	*SE*	*df*	*t*-value	Probability	
Model 1	M. corrugator	0.03	0.02	184.00	1.35	.177	
	M. orbicularis	0.10	0.02	184.00	4.60	< .001	***
	Cycle 2	- 0.03	0.01	278.00	-3.40	.001	**
	AI	- 0.04	0.01	91.00	-2.49	.015	*
Model 2	M. corrugator	0.03	0.02	184.00	1.35	.177	
	M. orbicularis	0.10	0.02	184.00	4.60	< .001	***
	Cycle 2	- 0.03	0.01	278.00	-3.40	.001	**
	Alexithymia	- 0.03	0.01	91.00	-2.00	.048	*

Note. Model 1*:* R^2_M = .06, R^2_C = .69; Model 2: R^2_M = .08, R^2_C = .69. AI = Autism Index.

*p < .05, **p < .01, ***p < .001.

Muscle Slope

Table 46

Linear Mixed-Effects Model Predicting Muscle Slope (incl. Cycle and Condition)

Fixed effects	*SS*	*MS*	df_{effect}	df_{error}	*F*-value	Probability	
Muscle	1252.28	626.14	2	85.43	4.83	.010	*
Cycle	1.33	1.33	1	587.13	0.01	.919	
Condition (Cond)	3.46	3.46	1	109.69	0.03	.871	
Alexithymia (Alex)	20.08	20.08	1	81.89	0.15	.695	
AI	0.01	0.01	1	82.63	0.00	.992	
Self-regulation (Self-reg)	148.41	148.41	1	83.16	1.14	.288	
P. cognitive empathy (PCE)	115.04	115.04	1	82.67	0.89	.349	

	Cor	Orb	Cycle 2	Cond: Self	Alex	AI	Self-reg	PCE
VIF	2.02	2.01	1.00	1.03	1.61	2.04	1.23	1.31

Note. R^2_M = .01, R^2_C = .34. AI = Autism Index; P = performance; VIF = variance inflation factor; Cor = Corrugator supercilii; Orb = Orbicularis oculi.

*p < .05, **p < .01, ***p < .001.

Autonomic Arousal

Table 47

Linear Mixed-Effects Model Outcomes Predicting Autonomic Arousal

Model	df_{effect}	df_{error}	*F*-value	Probability	R^2_M	R^2_C	σ^2_{ID}	σ^2_{resid}
PEP	4	366	7.33	< .001	.002	.975	395.95	10.02
Vagal control	4	374	3.27	.012	.027	.027	0.00	262.73
SCL	4	330	26.47	< .001	.008	.969	5.91	0.19
HR	4	374	11.66	< .001	.003	.973	138.35	3.87
Respiration	4	374	9.32	< .001	.019	.760	5.01	1.62

Note. Predictor: Time. PEP = pre-ejection period; SCL = skin conductance level; HR = heart rate.

Table 48

Linear Mixed-Effects Models of Cardiac Vagal Control and Skin Conductance (incl. Condition)

Fixed effects	β	*SE*	*SS*	*MS*	df_{error}	*F*-value	Probability	
Vagal control[a]								
Base vagal control	- 3.77	0.83	5257.75	5257.75	358.99	20.78	< .001	***
Medication	- 0.95	2.31	43.39	43.39	358.99	0.17	.679	
Condition	1.44	1.66	189.61	189.61	358.99	0.75	.387	
AI	- 0.17	1.07	6.22	6.22	358.99	0.02	.876	
Cycle	- 2.37	1.17	1033.25	1033.25	358.99	4.08	.044	*
Self-regulation	- 0.43	0.96	50.98	50.98	358.99	0.20	.654	
Concern	- 0.43	0.94	52.15	52.15	358.99	0.21	.650	
AI * Cycle	1.83	1.24	547.06	547.06	358.99	2.16	.142	
SCL[b]								
Base SCL	2.38	0.07	151.68	151.68	76.55	1027.64	< .001	***
Medication	- 0.01	0.20	0.00	0.00	78.60	0.00	.965	
Condition	0.00	0.04	0.00	0.00	232.98	0.00	.949	
AI	0.02	0.09	0.01	0.01	81.57	0.06	.805	
Cycle	- 0.12	0.03	2.46	2.46	242.26	16.65	< .001	***
Self-regulation	0.02	0.08	0.01	0.01	82.51	0.07	.792	
Concern	0.00	0.05	0.00	0.00	298.96	0.01	.930	
AI * Cycle	- 0.07	0.03	0.76	0.76	242.08	5.13	.024	*

Note. Both models: $df_{effect = 1.}$ [a] R^2_M = .07. [b] R^2_M = .91. AI = Autism Index.

Table 49

Average Autonomic Arousal During the First and Second Cycles of Painful Facial Expressions

Cycle	PEP (ms)		Vagal control		SCL (μS)		HR (bpm)	
	M	SD	M	SD	M	SD	M	SD
1	112.60	20.87	2.25	17.63	5.00	2.56	72.75	12.14
2	113.49	20.33	- 1.06	14.50	4.78	2.44	73.62	11.68
	Δ PEP (ms)		Δ Vagal control		Δ SCL (μS)		Δ HR (bpm)	
	M	SD	M	SD	M	SD	M	SD
1	-0.77	4.43	4.65	26.50	0.56	0.76	-0.83	3.09
2	0.11	5.12	1.32	25.37	0.37	0.65	0.16	2.69

Note. PEP = pre-ejection period; SCL = skin conductance level; HR = heart rate; bpm = beats per minute.

Table 50

Autonomic Arousal During the First and Second Cycles of Painful Facial Expressions by AI Group

Cycle	AI Group	PEP (ms)		Vagal control		SCL (μS)		HR (bpm)	
		M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
1	Low	113.11	22.75	2.74	20.33	4.42	2.33	70.81	11.41
	Medium	114.96	22.21	3.29	18.74	4.92	2.92	69.68	11.44
	High	109.43	16.90	0.59	12.76	5.68	2.23	78.19	12.02
2	Low	114.53	22.31	- 1.57	13.29	4.33	2.13	72.12	11.45
	Medium	115.22	20.80	- 1.63	17.61	4.75	3.00	70.91	10.85
	High	110.35	17.38	0.15	11.79	5.29	1.91	78.37	11.62
		Δ PEP (ms)		Δ Vagal control		Δ SCL (μS)		Δ HR (bpm)	
		M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
1	Low	-1.14	4.73	4.76	35.97	0.54	0.64	-0.65	3.10
	Medium	-0.42	4.46	5.61	23.42	0.53	0.68	-1.16	2.82
	High	-0.76	4.12	3.50	16.15	0.60	0.95	-0.64	3.38
2	Low	0.28	5.01	0.44	29.06	0.46	0.60	0.66	2.80
	Medium	-0.17	6.11	0.69	28.14	0.36	0.64	0.07	2.27
	High	0.27	3.92	3.03	16.44	0.28	0.71	-0.26	2.98

Note. PEP = pre-ejection period; SCL = skin conductance level; HR = heart rate; bpm = beats per minute.

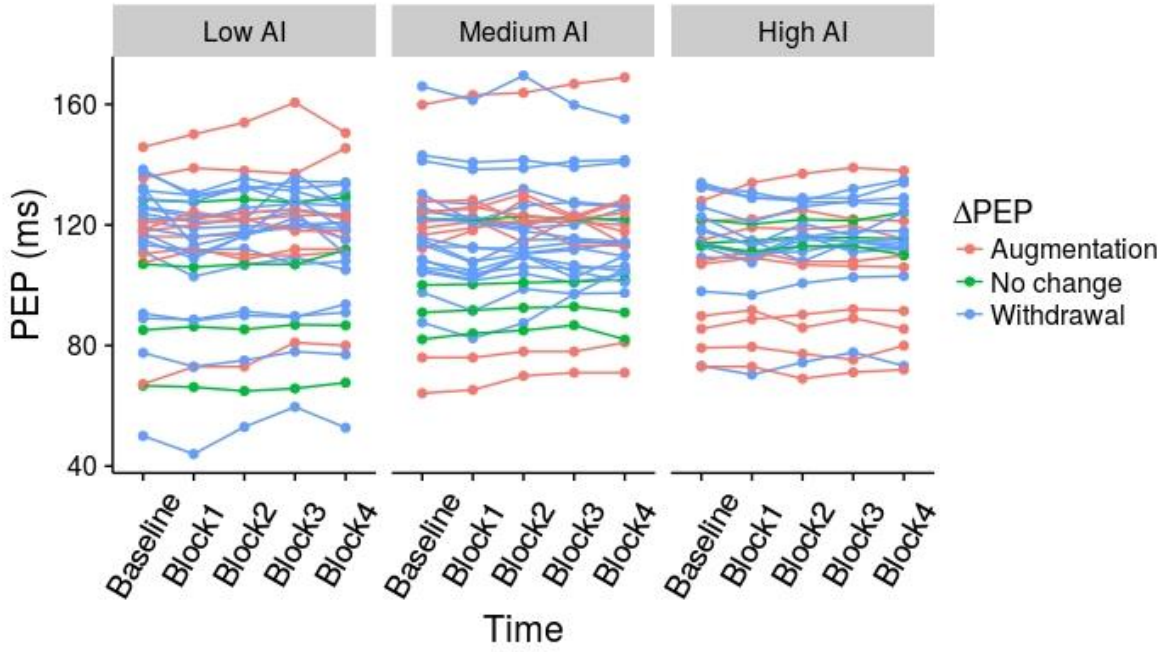

Figure 31. Pre-ejection period (PEP) over the different empathy-for-facial-pain conditions. The colours indicate whether participants primarily showed PEP augmentation or withdrawal from baseline, or whether there were no/small changes only in PEP. Individual lines show individual participant responses.

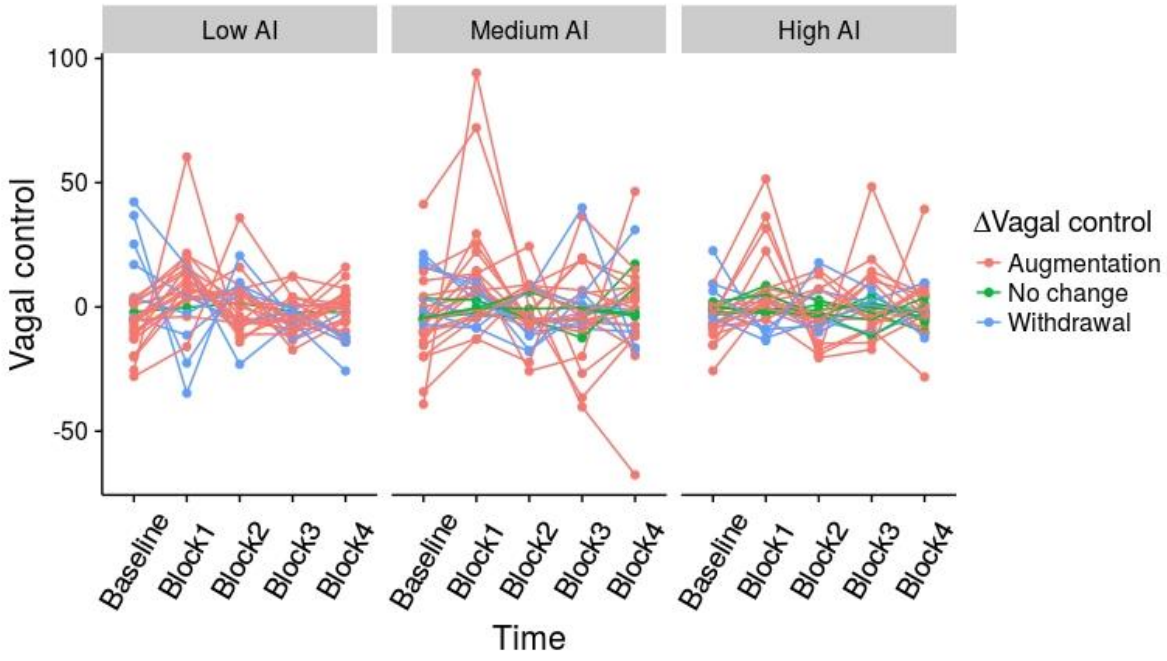

Figure 32. Cardiac vagal control over the different empathy-for-facial-pain conditions. The colours indicate whether participants primarily showed cardiac vagal control augmentation or withdrawal from baseline, or whether there were no/small changes only in cardiac vagal control. Individual lines show individual participant responses.

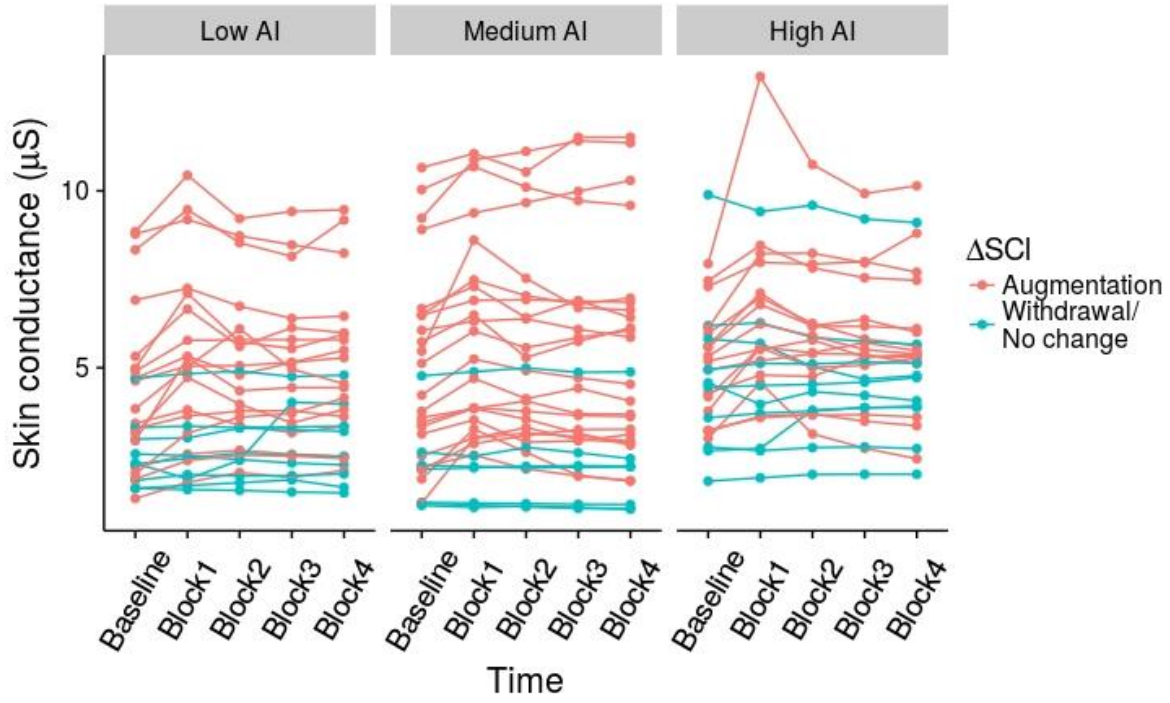

Figure 33. Skin conductance levels (SCL) over the different empathy-for-facial-pain conditions. The colours indicate whether participants primarily showed SCL augmentation or withdrawal/no change from baseline. As very few participants showed reductions in SCL from baseline, the withdrawal and 'no change' conditions were aggregated. Individual lines show individual participant responses.

APPENDIX Q

THE EMPATHY QUOTIENT

Below is a list of statements. Please read each statement *carefully* and rate how strongly you agree or disagree with it by circling your answer. There are no right or wrong answers, or trick questions.

IN ORDER FOR THE SCALE TO BE VALID, YOU MUST ANSWER EVERY QUESTION.

Examples

E1. I would be very upset if I couldn't listen to music every day.	strongly agree	slightly agree	slightly disagree	strongly disagree
E2. I prefer to speak to my friends on the phone rather than write letters to them.	strongly agree	slightly agree	slightly disagree	strongly disagree
E3. I have no desire to travel to different parts of the world.	strongly agree	slightly agree	slightly disagree	strongly disagree
E4. I prefer to read than to dance.	strongly agree	slightly agree	slightly disagree	strongly disagree
1. I can easily tell if someone else wants to enter a conversation.	strongly agree	slightly agree	slightly disagree	strongly disagree
2. I prefer animals to humans.	strongly agree	slightly agree	slightly disagree	strongly disagree
3. I try to keep up with the current trends and fashions.	strongly agree	slightly agree	slightly disagree	strongly disagree

(*continued*)

4. I find it difficult to explain to others things that I understand easily, when they don't understand it first time.	strongly agree	slightly agree	slightly disagree	strongly disagree
5. I dream most nights.	strongly agree	slightly agree	slightly disagree	strongly disagree
6. I really enjoy caring for other people.	strongly agree	slightly agree	slightly disagree	strongly disagree
7. I try to solve my own problems rather than discussing them with others.	strongly agree	slightly agree	slightly disagree	strongly disagree
8. I find it hard to know what to do in a social situation.	strongly agree	slightly agree	slightly disagree	strongly disagree
9. I am at my best first thing in the morning.	strongly agree	slightly agree	slightly disagree	strongly disagree
10. People often tell me that I went too far in driving my point home in a discussion.	strongly agree	slightly agree	slightly disagree	strongly disagree
11. It doesn't bother me too much if I am late meeting a friend.	strongly agree	slightly agree	slightly disagree	strongly disagree
12. Friendships and relationships are just too difficult, so I tend not to bother with them.	strongly agree	slightly agree	slightly disagree	strongly disagree
13. I would never break a law, no matter how minor.	strongly agree	slightly agree	slightly disagree	strongly disagree
14. I often find it difficult to judge if something is rude or polite.	strongly agree	slightly agree	slightly disagree	strongly disagree
15. In a conversation, I tend to focus on my own thoughts rather than on what my listener might be thinking.	strongly agree	slightly agree	slightly disagree	strongly disagree
16. I prefer practical jokes to verbal humor.	strongly agree	slightly agree	slightly disagree	strongly disagree
17. I live life for today rather than the future.	strongly agree	slightly agree	slightly disagree	strongly disagree
18. When I was a child, I enjoyed cutting up worms to see what would happen.	strongly agree	slightly agree	slightly disagree	strongly disagree
19. I can pick up quickly if someone says one thing but means another.	strongly agree	slightly agree	slightly disagree	strongly disagree
20. I tend to have very strong opinions about morality.	strongly agree	slightly agree	slightly disagree	strongly disagree
21. It is hard for me to see why some things upset people so much.	strongly agree	slightly agree	slightly disagree	strongly disagree
22. I find it easy to put myself in somebody else's shoes.	strongly agree	slightly agree	slightly disagree	strongly disagree
23. I think that good manners are the most important thing a parent can teach their child.	strongly agree	slightly agree	slightly disagree	strongly disagree
24. I like to do things on the spur of the moment.	strongly agree	slightly agree	slightly disagree	strongly disagree
25. I am good at predicting how someone will feel.	strongly agree	slightly agree	slightly disagree	strongly disagree
26. I am quick to spot when someone in a group is feeling awkward or uncomfortable.	strongly agree	slightly agree	slightly disagree	strongly disagree
27. If I say something that someone else is offended by, I think that that's their problem, not mine.	strongly agree	slightly agree	slightly disagree	strongly disagree
28. If anyone asked me if I liked their haircut, I would reply truthfully, even if I didn't like it.	strongly agree	slightly agree	slightly disagree	strongly disagree
29. I can't always see why someone should have felt offended by a remark.	strongly agree	slightly agree	slightly disagree	strongly disagree
30. People often tell me that I am very unpredictable.	strongly agree	slightly agree	slightly disagree	strongly disagree
31. I enjoy being the center of attention at any social gathering.	strongly agree	slightly agree	slightly disagree	strongly disagree
32. Seeing people cry doesn't really upset me.	strongly agree	slightly agree	slightly disagree	strongly disagree

33. I enjoy having discussions about politics.	strongly agree	slightly agree	slightly disagree	strongly disagree
34. I am very blunt, which some people take to be rudeness, even though this is unintentional.	strongly agree	slightly agree	slightly disagree	strongly disagree
35. I don't tend to find social situations confusing.	strongly agree	slightly agree	slightly disagree	strongly disagree
36. Other people tell me I am good at understanding how they are feeling and what they are thinking.	strongly agree	slightly agree	slightly disagree	strongly disagree
37. When I talk to people, I tend to talk about their experiences rather than my own.	strongly agree	slightly agree	slightly disagree	strongly disagree
38. It upsets me to see an animal in pain.	strongly agree	slightly agree	slightly disagree	strongly disagree
39. I am able to make decisions without being influenced by people's feelings.	strongly agree	slightly agree	slightly disagree	strongly disagree
40. I can't relax until I have done everything I had planned to do that day.	strongly agree	slightly agree	slightly disagree	strongly disagree
41. I can easily tell if someone else is interested or bored with what I am saying.	strongly agree	slightly agree	slightly disagree	strongly disagree
42. I get upset if I see people suffering on news programmes.	strongly agree	slightly agree	slightly disagree	strongly disagree
43. Friends usually talk to me about their problems as they say that I am very understanding.	strongly agree	slightly agree	slightly disagree	strongly disagree
44. I can sense if I am intruding, even if the other person doesn't tell me.	strongly agree	slightly agree	slightly disagree	strongly disagree
45. I often start new hobbies but quickly become bored with them and move on to something else.	strongly agree	slightly agree	slightly disagree	strongly disagree
46. People sometimes tell me that I have gone too far with teasing.	strongly agree	slightly agree	slightly disagree	strongly disagree
47. I would be too nervous to go on a big rollercoaster.	strongly agree	slightly agree	slightly disagree	strongly disagree
48. Other people, often say that I am insensitive, though I don't always see why.	strongly agree	slightly agree	slightly disagree	strongly disagree
49. If I see a stranger in a group, I think that it is up to them to make an effort to join in.	strongly agree	slightly agree	slightly disagree	strongly disagree
50. I usually stay emotionally detached when watching a film.	strongly agree	slightly agree	slightly disagree	strongly disagree
51. I like to be very organized in day-to-day life and often make lists of the chores I have to do.	strongly agree	slightly agree	slightly disagree	strongly disagree
52. I can tune into how someone else feels rapidly and intuitively.	strongly agree	slightly agree	slightly disagree	strongly disagree
53. I don't like to take risks.	strongly agree	slightly agree	slightly disagree	strongly disagree
54. I can easily work out what another person might want to talk about.	strongly agree	slightly agree	slightly disagree	strongly disagree
55. I can tell if someone is masking their true emotion.	strongly agree	slightly agree	slightly disagree	strongly disagree
56. Before making a decision I always weigh up the pros and cons.	strongly agree	slightly agree	slightly disagree	strongly disagree
57. I don't consciously work out the rules of social situations.	strongly agree	slightly agree	slightly disagree	strongly disagree
58. I am good at predicting what someone will do.	strongly agree	slightly agree	slightly disagree	strongly disagree
59. I tend to get emotionally involved with a friend's problems.	strongly agree	slightly agree	slightly disagree	strongly disagree
60. I can usually appreciate the other person's viewpoint, even if I don't agree with it.	strongly agree	slightly agree	slightly disagree	strongly disagree